50L HOME COALITION | JUNE 2021

A CIRCULAR WATER FUTURE

White Paper on how cities can integrate water reuse and transform their water systems

50L HOME

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Our thanks also go to the numerous colleagues and experts from other organizations in China, India, Mexico and the USA who provided input and feedback on various workshops and consultations.

This document takes into account the particular instructions and requirements of 50L Home Coalition and its member organizations.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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FOREWORD

Climate change is here, and one of its most evident impacts is the increasing and widespread water stress experienced by cities globally. As communities, governments and businesses begin to recover from the deep and tragic impacts of COVID-19, delivering on the powerful mission of the Sustainable Development Goal 6 to "ensure availability and sustainable management of water and sanitation for all" becomes more important than ever.

In response to the complex challenges our water and energy systems are facing, our 50L Home Coalition begins to play a vital role. We want to enable the ideation and creation of irresistible innovations to transform urban water into zero-carbon, safe, and sustainable systems. Reinventing our city systems is a challenge, and an opportunity, our generation cannot miss.

Critical approaches to transform water systems include transformative actions to reduce water consumption, remove water from day-to-day activities, and reuse this vital resource in our homes and cities. Water reuse solutions have been explored and tested for over a decade but have not been widely adopted.

Our Coalition's first publication focuses on exploring new ideas and opportunities to integrate water reuse in our homes and cities. It articulates the emerging potential of residential water reuse solutions globally and identifies the barriers and enablers to its adoption.

Throughout the collaborative work that informs this White Paper, we found that water reuse technologies are often perceived as an innovation frontier. As policies and standards are only beginning to recognize the multiple benefits of water reuse, innovators operate in an unfavorable environment.

We realized the diversity of scales and possible entry points for city leaders and practitioners are multiple, but they are rarely articulated in an actionable manner.

We also confirmed the important role of collaborations and partnerships and learned how these have enabled early successes in diverse geographies like China, India, Mexico and the USA.

This White Paper on water reuse is the first knowledge product created by the 50L Home Coalition. We intended not only to explore and recognize the opportunities for a transformative water reuse approach, but also to provide a suite of tangible actions government, civil society and public sector organizations can draw on strategically.

Our hope is that this will lead to new opportunities to adopt and localize water reuse innovations so they become more accessible and irresistible, and ultimately transform urban water into zero-carbon, safe and highly sustainable systems.

EXECUTIVE SUMMARY

This White Paper highlights the current global challenges faced by our domestic water sector, including case studies from China, India, Mexico and the US, and provides a menu of leverage options through water reuse that decision makers, policy makers and city planners can consider to augment the impressive steps towards systemic transformation that cities have begun undertaking.

Water consumption patterns vary in cities, from 14 to 538 liters per person per day in cities in Uganda and the US respectively. The global demand for fresh water is soon predicted to outstrip the world's supply. Innovation and alternative solutions are vital to prevent 'Day Zero' scenarios, overcome service disruptions and avoid harmful impacts on people's livelihoods.

50L Home Coalition proposes that the solution to the water crisis starts at home and the answer should not involve a sacrifice in people's quality of life. Our ambition is to achieve a "daily 50L per person living that feels like 500L".

To deliver on this vision for the future, we recognize multiple actions such as reducing water consumption, removing water from products and processes, and reusing water safely need to be tested and adopted in cities globally. Water reuse plays a key role in a future where water is sustainably available for all.

The evidence we gathered in the research and engagements that led to this White Paper suggests the development and deployment of water reuse solutions in cities is often done piecemeal. Whilst water reuse alone does not have the capacity to solve the water scarcity in urban areas, experts and practitioners suggested a more strategic and systemic approach to integrate water reuse solutions and practices can make a substantial contribution to address water stress in cities globally.

GLOBAL CONTEXT

To identify relevant opportunities for water reuse in cities, three key dynamics need to be taken into consideration.

First, water scarcity is widespread. With the growing context of fast increasing water stressed cities, we must rethink how we use and reuse our water. It is estimated that 3.6 billion people currently live in areas that experience water scarcity at least one month a year [2].

Second, building systemic resilience is a key factor for future investments in water infrastructure. Different reuse solutions are available and can be implemented as part of retrofitting existing homes or building new ones. Locating resilience at the core of urban systems design can help decision makers to identify the most relevant solutions.

Third, water use in cities and the performance of the system is determined by local factors. The current traditional linear water systems might only use water once before disposing it back into the environment. Considering the carbon footprint and overall costs involved as water moves through the cycle, adaptation and innovation in the water sector are a logical next step.

Despite significant challenges, circular water reuse solutions create room for optimism where we use water again and again, contributing to the overall resilience of the urban water system. This is along with other demand management techniques such as water efficiency and water conservation.

HOW URBAN HOUSEHOLDS USE WATER

Whist technological development in recent years has resulted in substantial advancements, many of those are difficult to integrate in existing homes, either due to lack of space or the required works needed for the plumbing systems due to necessary retrofit.

Across the world, water efficiency measures are progressing and examples from China, India, Mexico and the United States of America show how reuse is becoming a part of strategies to build urban water resilience.

In **China**, pilot projects have demonstrated that Government-backed financing incentives have unlocked implementation challenges. Establishing shared key performance indicators related to water reuse would enable the Government and siloed organizations to align action towards, and achieve, the targets of the national Five-year Plan.

India's size and development path suggests achieving scale is an urgency for water reuse innovations. Advancing successful pilot projects and the use of community-based platforms (schools, community groups, social media) will promote the acceptance and benefits of water reuse in growing cities.

In **Mexico**, the successful roll-out of rainwater harvesting systems, provides a model for local and national authorities. On this basis, collaborative work shall expand the innovation scope towards establishing policies and regulations to promote and co-implement other water reuse technologies, to mitigate periods of low rainfall.

Water reuse implementation has been successful in several states across the **USA**. Increasing peer to peer dialogue opportunities, demonstrative on site pilots, and investments in localized water strategies will help many cities in identifying the right scale to plan and implement water reuse solutions that are appropriate to their local context.

A SYSTEMS APPROACH

To date, water reuse technologies have been more widely adopted at the city scale, rather than for individual households, in response to local water resource challenges and with a good level of success. Water reuse at household, neighborhood, and even regional scale also provide further opportunities for a radical systemic transformation of water use in our cities.

This White Paper summarizes the opportunities, available solutions and key considerations for the implementation of reuse systems across four key scales of intervention: household, neighborhood, city and regional.

In each of the scales, the deployment of water reuse solutions should consider their impacts on the wider infrastructure. This multi-scale framework can help policy makers to identify the most appropriate entry point for their local context, depending on local policy, infrastructure coverage and local water stress conditions.

LEADING SYSTEMS TRANSFORMATION

City, regional and national governments can play a key role in reinventing water systems by investing in innovation as well as aligning their modus operandi towards value creation. Recognizing global urgencies associated with climate change and the priorities articulated by the SDGs, innovation in water reuse should not remain a 'water sector' concern, but rather as an agenda that simultaneously addresses water stress, decarbonization and human outcomes.

While solutions vary from city to city, three levers are key in all locations:

A culture of innovation and partnerships: Using research and collaboration to stimulate innovative ideas for adoption of products or services supporting water reuse. Through deep collaboration, innovations in the water sector shall be 'de-siloed' and integrate key drivers such as water stress, climate mitigation and human outcomes.

Awareness and Desirability: Creating community trust and demand for water reuse through education as well as creating solutions that do not compromise user experience. By exploring local needs, organizations in the public and private sectors, as well as academia and civil society, can build a shared and holistic understanding of local resource constraints (including water stress) as well as the complex impacts of climate change.

Adaptive Planning and Policy: As a result of their engagement in building an innovative environment to rethink its water systems, government agencies will be in a better position to create a locally relevant strategy that clearly sets out a city's (or region's) water and climate-related priorities and key investments. A clear strategy helps decision makers in all sectors - including citizens – to make better decisions on their opportunities to act on reducing water stress and carbon emissions.

INTRODUCTION

The global water crisis needs us to adopt circular economy solutions alongside reducing consumption significantly and make changes at the household level.

The current average water use per day in some cities such as Los Angeles and Denver, USA is as high as 428 and 538 liters respectively [1].

Such levels of consumption are also noticeable in Global South cities such as Mexico City and Buenos Aires, with average daily consumption of 336 and 312 liters respectively. The City of Cape Town, South Africa is an example of how household water per capita consumption can be reduced dramatically providing its urgency is clearly articulated by authorities.

The City of Cape Town, South Africa, a city of 4 million, dramatically reduced its water consumption in a response to a drought that had seen three consecutively dry winters. In early 2018, the City limited household water usage to 50 liters per person per day.

The campaign resulted in a 60% reduction in water consumption from previous levels of usage.

Similar levels of water efficiency are broadly required across water stressed urban areas, but efforts will be unsuccessful unless new solutions are sufficiently attractive to citizens so that they integrate them into their daily lives.

WHY WATER REUSE

Our 50L Home Coalition seeks to develop, scale, and implement innovations for systems level change in household urban water and energy usage in the home.

We aim to reinvent our water future through coordinated, collaborative actions at city-level, where business and community-led innovations, public policy and financial instruments together enable consumer choices that reduce both water consumption and energy inefficiencies in the household.

50L Home Coalition proposes that the solution to the water crisis starts at home and the answer should not involve a sacrifice in people's quality of life. Our ambition is to achieve a "daily 50L per person living that feels like 500L".

To deliver on this vision for the future, we recognize multiple actions such as reducing water consumption, removing water from products and processes, and reusing water safely need to be tested and adopted in cities globally. Water reuse plays a key role in a future where water is sustainably available for all.

The evidence we gathered in the research and engagement that led to this White Paper suggests the development and deployment of water reuse solutions is often done piecemeal. City and regional governments rarely develop water strategies and normally lack multi-stakeholder platforms to identify solutions for water scarcity. Whilst water reuse alone does not have the capacity to solve water scarcity in urban areas, experts and practitioners consulted globally suggested a more strategic and systemic approach to integrate water reuse solutions and practices can make a substantial contribution to address water stress in cities globally.

This White Paper articulates the potential of residential water reuse solutions. It explores four key aspects:

1. Current water-related challenges cities experience

2. How urban households use water

3. A systemic approach to deliver water reuse at multiple scales

4. How cities can articulate and lead a system-wide transformation agenda

RESEARCH APPROACH

Our consultants Arup conducted research and evidence gathering using multiple methods, bringing together the synthesis and insights in this paper.

Evidence Gathering

Evidence was captured through a series of workshops and an extensive literature review. This included consultees from 19 various organizations from technical, private, government, regulatory, policy makers and international organizations.

Their experience covered numerous geographies, with an emphasis on China, India, Mexico, and the USA, as well as a global perspective on water reuse. These workshops helped us to understand the consultee's experiences, particularly on challenges, barriers, and enablers. Relevant case studies were identified in these workshops too.

The insights from the workshops were supported by a literature review of 69 secondary sources, including national standards and regulations, academic papers, journal articles and other peer reviewed documents. The literature review incorporates both qualitative and quantitative data.

Synthesis

We synthesized the evidence through a social, technological, environmental, economic and political (STEEP) lens for the global household water reuse landscape and for the four focus countries.

We identified key drivers, strengths, challenges and proposed enablers in order to understand the geography specific priorities to adopting widespread adoption of water reuse.

It should be noted that publicly accessible data relating to water reuse varies enormously across the world and thus stakeholder interviews were used to fill any gaps in the literature and data.

ABOUT 50L HOME

50L Home Coalition is a global initiative that addresses two of our most pressing global challenges: water security and climate change.

50L Home Coalition was launched in October 2020 supported by an emerging group of global private partners, including Electrolux, ENGIE, Kohler, P&G, Suez, and Arcadis, and convened by the World Economic Forum, the 2030 Water Resources Group at the World Bank, and the World Business Council for Sustainable Development.

Our Coalition brings together companies, policymakers, cities, and citizens to solve the combined water and energy consumption challenges in cities through a systems transformation approach. Beyond water security, 50L Home will also support climate change objectives as the supply of water has energy and carbon impacts and the heating of hot water is a significant use of energy in the home.

Drawing on our unique connection to private sector know-how and the innovations created in collaboration with public sector and civil society partners, our vision is to contribute to cities globally by pioneering irresistible innovations that transform urban water into zero-carbon, safe, and sustainable systems. Join us.

A CIRCULAR APPROACH TO WATER SYSTEMS

With a changing climate and increasing demand for fresh water to meet the needs of growing populations, the ways we use, and reuse water are more important than ever.

In a future with increasingly competing demands for fresh water from agriculture, industry, and commerce, transitioning to a circular economy will lessen our impact on the environment. The adoption of water reuse at scale reduces the reliance on fresh water for household use and provides low-cost local solutions, especially in places where the water infrastructure is inefficient or insufficient. Water reuse is a priority solution that can introduce water circularity at different scales, ranging from household to city.

Overall water resilience is improved through the provision of circular water reuse solutions to augment traditional linear water systems where water is used only once. This transformation provides opportunities for innovation in products and services that meet the unique contexts of individual countries.

Treatment of wastewater will always be necessary to manage water systems for long-term sustainability, but a circular approach offers opportunities for commercial enterprise too. Along with improvement and adoption of new products and water demand management, water reuse can contribute greatly to the overall reduction of water consumption, while maintaining a high level of performance and satisfaction for end users.

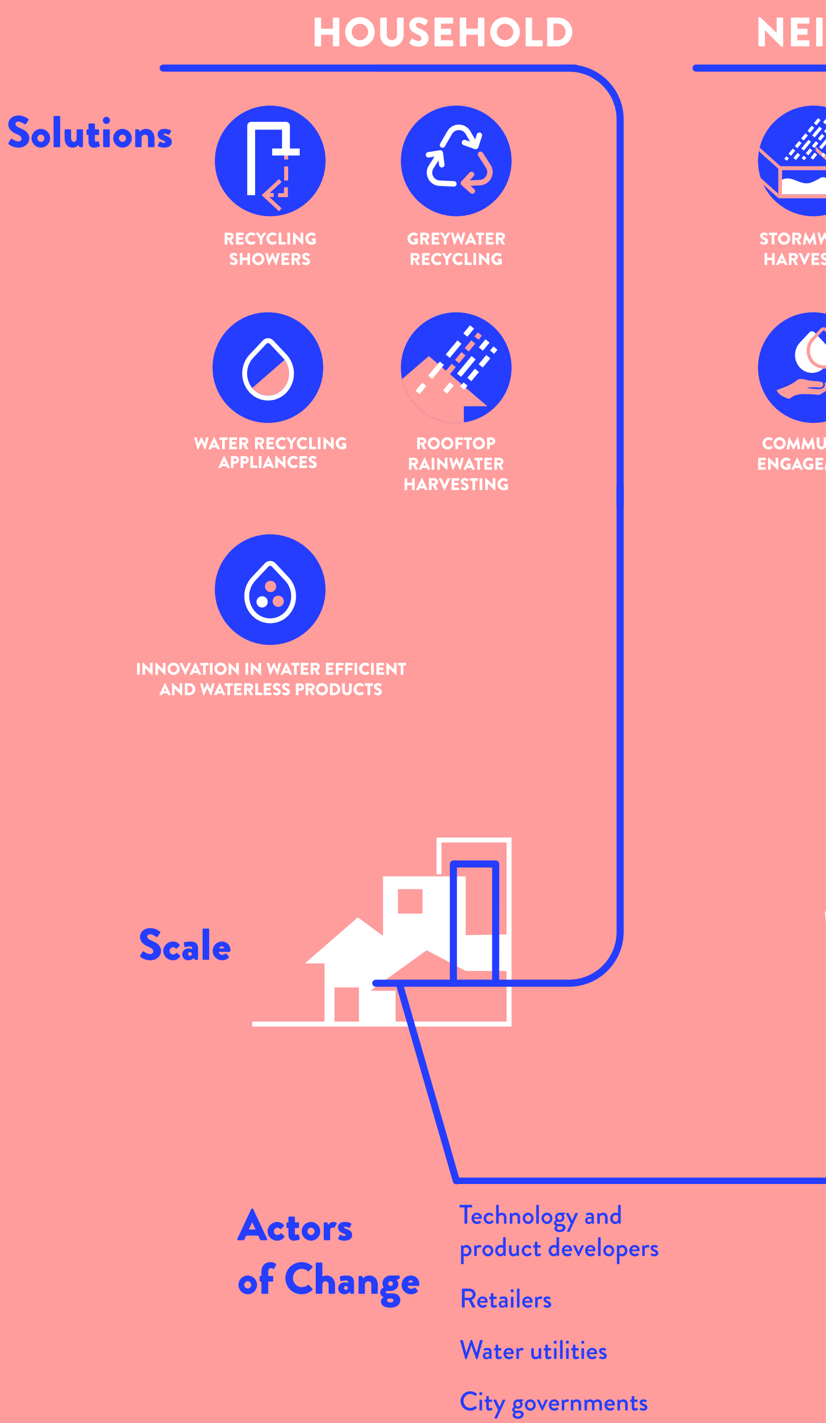
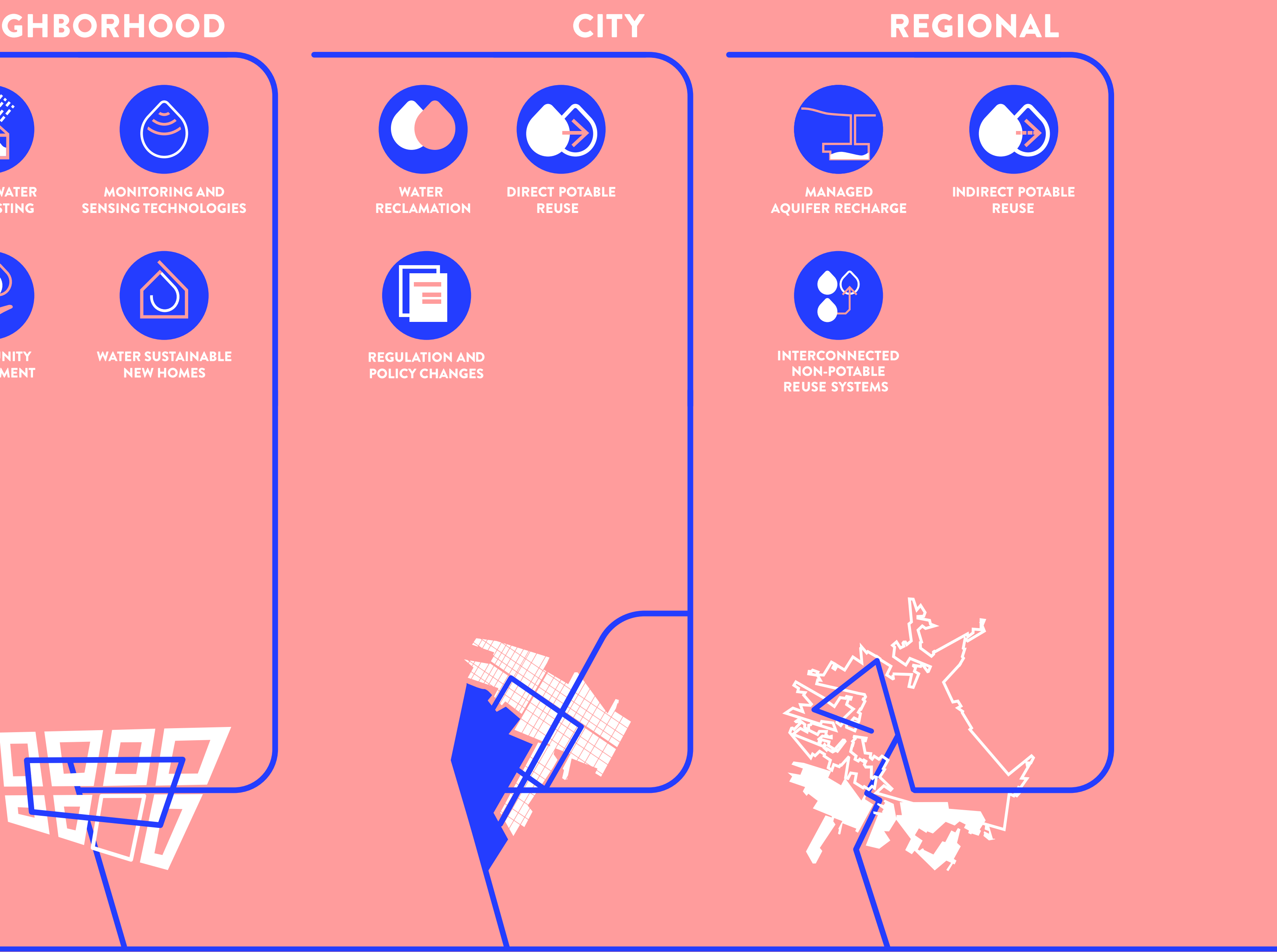


Figure 1: Scales of Circular Water



Technology and product developers

Housing developers

Water utilities

City planners

Technology and product developers

Water utilities

City government

Public-private partnerships

Water reuse potential as four scales

Improving human adaptiveness and leveraging natural water cycle

National and regional governments

Water utilities

Water Resource Management Authorities

Corporations and Philanthropies

1. GLOBAL CONTEXT

REDUCING GROWING WATER STRESS IN CITIES

Cities and populations are continuing to grow but resources are limited [2]. While global household water demand has increased by 600% since the 1960s [3], global fresh water supply is decreasing due to water stress and pollution.

Reduction in accessible water resources is largely created through groundwater depletion, with more than 30% of the world's largest groundwater systems classed as 'distressed' [4].

UNESCO estimated 3.6 billion people currently live in areas that experience water scarcity at least one month a year; and it is predicted this worrying figure will further increase to six billion people by 2050 due to compounding impacts of climate change [2].

Fresh water withdrawals are continually increasing globally. However, 10% of the global population still lack access to even a basic water supply [5]. There is vast inequality in water accessibility correlated with wealth, both between countries and within cities.

The global demand for fresh water is soon predicted to outstrip the world's supply. Innovation and alternative solutions are vital to overcome service disruptions and harmful impacts on people's livelihoods.

There is a growing list of cities under threat of a potential 'Day Zero' scenario as experienced by Cape Town, South Africa. This threat of severe drought affects not only water supply but results in severe and cascading impacts [78].

Chennai, India, saw its four reservoirs run dry in 2019 despite the city being prone to flooding. In Brazil, São Paulo's water supply came within 20 days of running short of supplying water to its 21.7 million inhabitants in 2015. These examples are stark reminders of worsening water scarcity and influences of climate change on the global water supply.

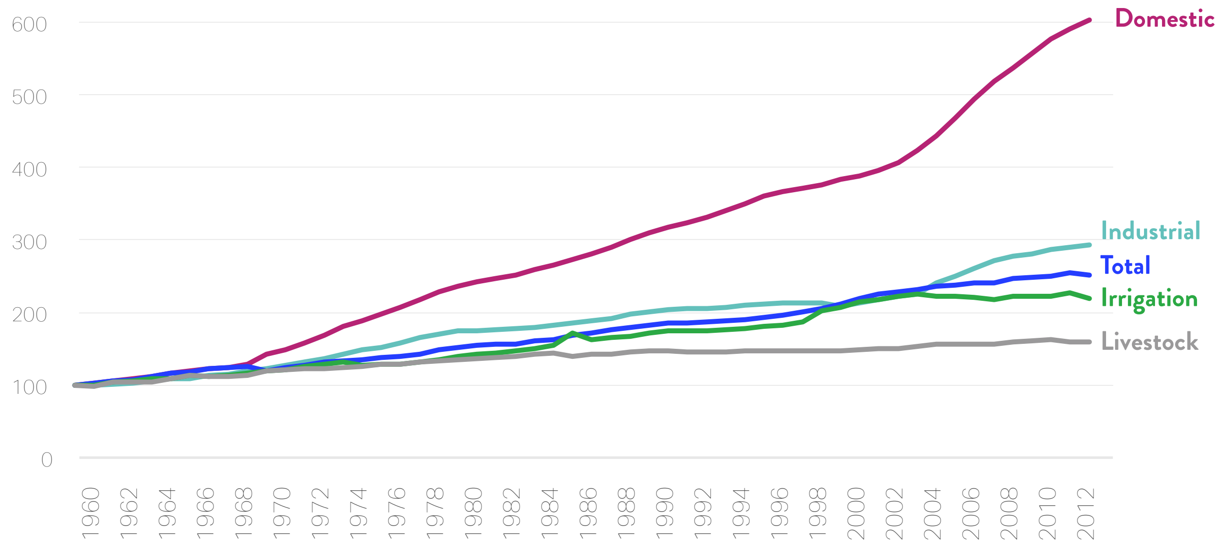


Figure 2: Global Percentage (%) Increase of Water Withdrawals by Sector since 1960

It is estimated that between five to 30% of the total operating cost of water and wastewater utilities is from energy use [6].

Measures to increase the energy efficiency of water recycling and reuse and advance energy neutrality are vital to achieving net-zero targets [7].

The evident combined impacts of climate change, growing inequality and supply deficit highlight the need to adapt quickly. To respond to this existential threat, cities globally must develop new approaches to ensure water is used efficiently so citizens can do more with less. It will require a all-encompassing approach to transform and build water resilience at all scales.

BUILDING RESILIENCE THROUGH WATER REUSE

A resilience-based approach recognizes a number of 'qualities' that need to be promoted across city systems [8]. These qualities are important characteristics that prevent service breakdown or failure.

Urban systems that are resilient can better respond and recover from crisis, and are less prone to service breakdown or failure.

Adding water reuse into the mix of household water services provides 'resourcefulness' strategies to withstand times of scarcity. Water reuse solutions provide targeted and scalable solutions to provide spare capacity, 'redundancy', in times of water stress and add local low-cost solutions to overcome infrastructure constraints.

Different technological reuse solutions are available and can be implemented as part of retrofitting existing homes or building new ones.

Where current water infrastructure is lacking, cities should be 'reflective' and potentially 'leapfrog' to water reuse technologies. Decentralized solutions provide an alternative to traditional centralized systems that require long-term planning and investment.

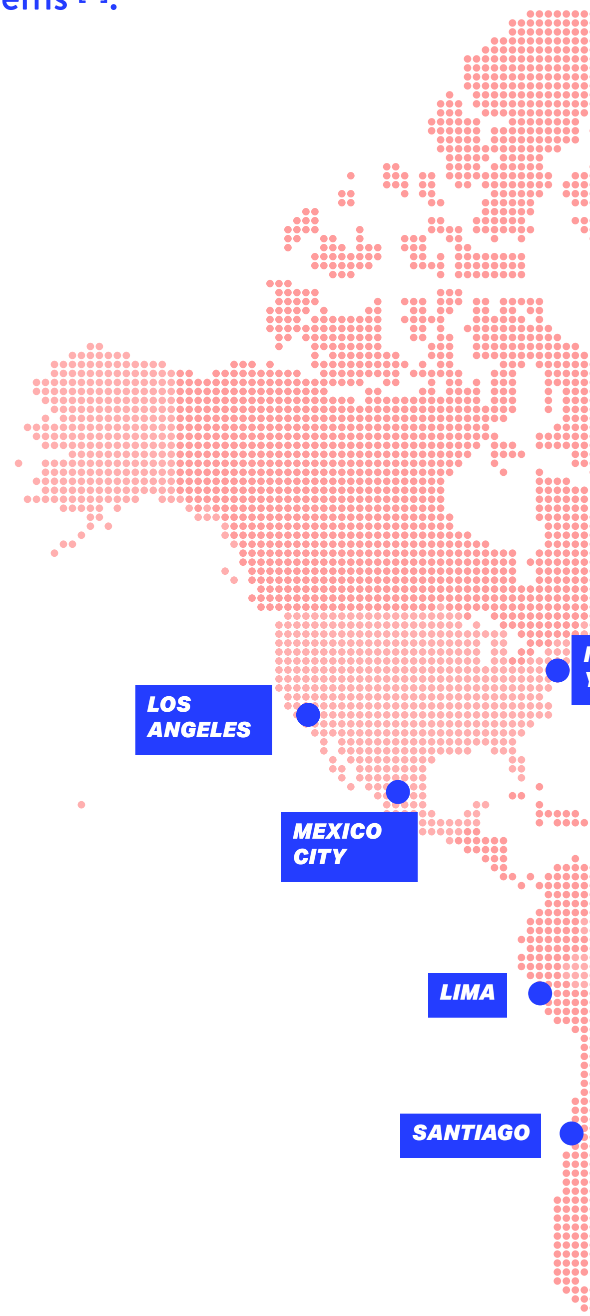
Digital innovations including sensors and artificial intelligence help to better manage the demand-supply characteristics of water reuse, making systems more adaptable to change. Water reuse provides the opportunity to 'integrate' actions across sectors, systems, and scales, and create a positive relationship between sustainable energy and water reuse.

RESILIENCE CO-BENEFITS

The treatment, delivery and subsequent disposal of water will have an energy use linked carbon footprint, which will vary depending on the local mix of energy sources. This carbon footprint can be significant, with water related carbon footprint in USA estimated at 5% of all emissions [64]. In addition, the energy use for hot water in the home can be significant. Many countries are pursuing a decarbonization strategy for compliance with their climate commitments, including in the water systems.

Costa Rica's decarbonization plan considers that by 2050, 50% of commercial, residential and institutional buildings will operate under emission standards. This means high electrification or renewable energy is to be used in cooking processes and water heating [71]. The UK's water industry has set five demanding goals including a pledge to reach net zero on operational emissions by 2030. The country has estimated savings of up to 10 million tonnes of greenhouse gas by the Government's legally binding and target net zero commitment by 2050 [72].

Solutions for water systems include low energy water reuse solutions, and heat recovery from greywater and wastewater to reduce energy use of hot water in the home. Innovative solutions that integrate these heat recovery systems with water reuse systems provide additionality that reduce both water and carbon footprints.



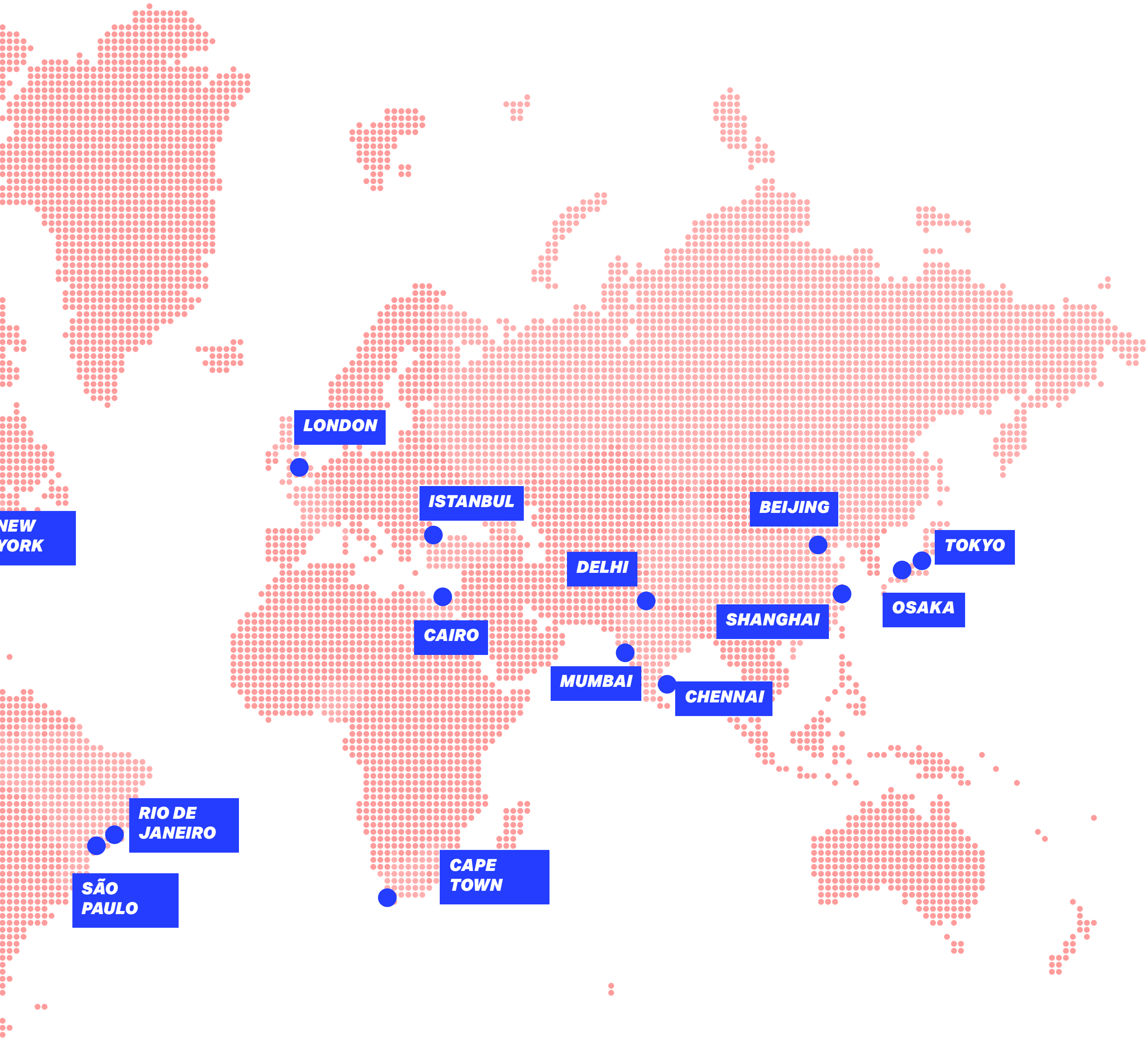


Figure 3: Global Map [9] showing Cities Experiencing Water Scarcity

CHALLENGES OF WATER REUSE

It is important to understand the key characteristics of water systems in cities to be able to deliver a locally-relevant circular water agenda. Understanding and addressing key issues related to water reuse will help unlock the potential for a circular system.

THE CURRENT LINEAR SYSTEM

Typically, a city's water follows a linear journey. It is drawn up from sources, treated for use, distributed to consumers and disposed, in some cases after treatment. Disposal of untreated wastewater can cause environmental degradation. This represents a 'Take-Make-Dispose' approach that supports the existing business model of charging users per liter of water. This pays for the operations and leverages finance for capital expenditure.

This model is underpinned by the assumption that water resources are plentiful and cheap. This is proven to be wholly incorrect by the increasing fresh water scarcity being experienced globally.

INTRODUCING CIRCULARITY IN THE WATER SYSTEM [6] REDUCES THE RELIANCE ON FRESH WATER SOURCES AND FOSTERS BETTER ENVIRONMENTAL STEWARDSHIP.

UNEQUAL ACCESS TO INFRASTRUCTURE

In cities, there is a high reliance on infrastructure for safe water provision that is beyond individual ownership and control. Water infrastructure supports the collection, treatment, distribution, and discharge of water. There is a general perception that investing in water supply and storage infrastructure or large-scale transfers is the only way to solve the supply deficit.

Water infrastructure is not equal everywhere – some places may have developed water infrastructure systems providing sufficient, safe, and reliant water service while in other places, less developed or poorly performing water infrastructure systems may not provide the required volume or quality of water.

WATER REUSE PROVIDES TARGETED AND LOW-COST SOLUTIONS TO COMMUNITIES WHO DO NOT HAVE ADEQUATE PROVISION AT THE HOUSEHOLD LEVEL.

GROUNDWATER EXTRACTION

A city may experience contradictory conditions of too much water and too little water at the same time. For example, to compensate for lack of water supply, many regions use groundwater. If this is overexploited, not only can the water quality and quantity deteriorate, but the ground may subside creating new areas for potential flooding as seen in many cities such as Mexico City, Mexico and Semarang, Indonesia. In Windhoek, Namibia, the local water utility has produced drinking water from recycled wastewater since the 1960s and has recharged its aquifers with surplus reclaimed water since the mid-2000s [73].

REDUCING THE DEMAND FOR WATER CAN REDUCE THE PRESSURE FROM WATER EXTRACTION PROCESSES. IT CAN ALSO ALLEVIATE ISSUES WITH COMPETING DEMAND AND THE NEED FOR INVESTMENT IN LARGE SCALE TREATMENT AND DISTRIBUTION INFRASTRUCTURE.

WATER RESOURCES ARE UNDERVALUED

Water is perhaps one of the most overlooked resources – until the time that it becomes scarce and its true value becomes apparent. True costs include direct costs such as abstraction charges, infrastructure costs and operational costs.

Indirect costs might include the impact of over abstraction on the environment and the impacts of water shortages on society and the economy. Tariffs for combined water and wastewater costs in 2018, range from $0.4 to $4.2 per 1000 liters in South Asia and North America respectively [79].

Water reuse provides an opportunity for the provision of an alternative water source to supplement fresh water sources. As well as reducing reliance on fresh water abstractions, this alternative source provides a more diverse system to enhance the overall water resilience of a neighborhood or city.

WATER REUSE AT THE HOUSEHOLD LEVEL WILL CHANGE PERCEPTIONS TO APPRECIATE THE VALUE OF FRESH WATER SOURCES MORE HIGHLY. SIMULTANEOUSLY REDUCING THE PRESSURE OF THE HIGH FINANCIAL AND ENVIRONMENTAL COSTS OF FRESH WATER RESOURCES.

WATER SAFETY IS OFTEN OVERLOOKED

Like all water resources, water reuse systems need to be carefully designed, installed, and managed to maintain health and hygiene standards. Technical standards exist for the suitable 'fit-for-purpose' water reuse. Well-established Water Safety Planning (WSP) guidelines provide for the design and operation of water systems. Currently, some quality standards are more readily monitored and managed at larger scales of water provision.

The application of water reuse systems reduces the demand on fresh water systems. This is turn provides additional capacity for essential water uses such as handwashing and personal hygiene to protect public health and to help minimize COVID-19 transmission. It is potentially impactful in areas where purification capacity is limited in comparison with demand.

THE COVID-19 PANDEMIC HAS SHOWN US THE IMPORTANCE OF WATER FOR PERSONAL WASHING AND HYGIENE. WATER REUSE WILL PROVIDE ADDITIONAL CAPACITY FOR COMMUNITIES TO MEET THESE ESSENTIAL REQUIREMENTS TO HELP PROTECT PUBLIC HEALTH.

TIME AND SCALE OF CHANGE

Water reuse provides a significant opportunity to increase urban water resilience specifically to meet water supply issues. Around the world, there are many cities facing deficits between supply and demand. Simultaneously, cities are facing growing populations, ageing infrastructure, and complex uncertainties including climate change.

Recognizing the complexity of the issues, some cities like London are working with water companies, regulators, NGOs, professional bodies, and others to encourage more water reuse in the city. The plans include updating guidance, information sharing, exploring incentives, reviewing national regulations, pilot projects and assessing the impact of the implementation of planning policy.

WATER REUSE SOLUTIONS PROVIDE OPPORTUNITIES TO CREATE IMPACT AT HOUSEHOLD, NEIGHBORHOOD, AND CITY SCALES. THIS PROVIDES A MIX OF SOLUTIONS DEPENDING ON THE LOCAL CONTEXT AND THE SPEED OF TRANSFORMATION REQUIRED.

CONSUMER BEHAVIOR CHANGE IS NEEDED FOR SUSTAINABILITY

Droughts including Cape Town (2017-18) and Australia (the 'Millennial Drought') have shown the acceptance of water reuse by communities. Positive communication, including government messaging and media, on the benefits of water reuse during these periods encouraged the uptake of water reuse systems and overcame any negative perceptions.

Cape Town's positive communication and positive public dialogue around water reuse and its benefits is a valuable example that can be adopted elsewhere.

Promoting the positive outcomes of the adoption of water reuse technologies will help overcome any public perception issues related to this type of water resources.

TRADE-OFF WITH ENERGY AND CARBON IS NECESSARY

Operational energy and carbon impacts are also a consideration for water reuse systems. The carbon footprint of water reuse systems must be considered when making choices to meet demand or displace mains water supply with recycled water. Decisions made to adopt new technology for water reuse should consider trade-offs, including energy, water and materials.

A study has shown that the operational energy from a number of rainwater harvesting and greywater recycling systems, with some exceptions, gave rise to higher carbon emissions than those arising from the supply of mains water in the UK [65].

The water management hierarchy favors water efficiency and conservation measures for households to be adopted prior to water reuse. This reduces embodied CO_2 emissions as water reuse systems often require additional technology and pipework. The trend towards decentralized renewable energy sources, such as solar energy, could provide a spur for adopting local water reuse systems for households.

INNOVATION IN WATER TREATMENT SYSTEMS AND THE CO-DEVELOPMENT WITH RENEWABLE ENERGY SOURCES SHALL PROVIDE WATER REUSE SYSTEMS THAT CONTRIBUTE TO NET ZERO CARBON INITIATIVE.

2. HOW URBAN HOUSEHOLDS USE WATER

There is a wide range of water consumption in cities worldwide, from 14 through to 538 liters per person per day (lppd), in Mbarara, Uganda and Denver, USA respectively [1].

The World Health Organization (WHO) advocates that between 50 and 100 lppd are needed to ensure the most basic service needs are met [10].

Driven by the unprecedented Millennium Drought (1997-2010), Australia became the first country to adopt national potable reuse guidelines called the Australian Guidelines for Water Recycling (AGWR). The support of national, local, and state governments contributed to the country's widespread adoption of water reuse and recycling. For example, the State Government of Queensland has mandated that households in South East Queensland must have an on-site water reuse device that can save up to 70 kL of annual potable mains water [11].

Namibia's historical record of water crises paired with an average annual rainfall of 370 mm, has driven maximum water reuse as a major policy to Windhoek's Water Demand Management Plan as is seen in the Gorenangad Water Reclamation Plant [12].

The public's wide acceptance of the reclamation plants is attributed to the active engagement and education strategies employed by the federal and local governments.

Singapore, through investments in technology and water management as part of its "Four National Taps" Strategy, has maximized the utilization of its four water sources, which are from: locally managed catchment areas, imports, reclaimed sources, and seawater desalination.

Water demand at the household level is managed through pricing, mandates, and conservation practices. A key component of demand management is the mandatory Water Efficiency Labelling Scheme on water fittings and household appliances, which allows consumers to make more informed decisions [66] [67].

As Cape Town approached 'Day Zero' in 2018, a 50 lppd measure was implemented by law by the City of Cape Town.

A guide was published to instruct the inhabitants of Cape Town where household water usage could be divided and spared, to meet the requirement. Cape Town's household water-use breakdown during its implementation of 50 lppd is compared to the average water-use in San Francisco and Beijing, Figure 4 illustrates where major savings of potable water can be made.

Figure 4: Breakdown of Water Use in the Home in liters per person per day (lppd) [13] [1] [14]

ARE EXISTING TECHNOLOGIES ENOUGH?

Water reuse can be found in most cities, but not extensively so. These systems are typically operated and financed by water utilities, which may be publicly or privately run.

Households across the globe already reuse water, from using basic 'home-made' solutions to using sophisticated onsite treatment technologies.

Technology exists for recycling water for other appliances such as recycling showers that recirculate water and enable saving of up to 90% of water and 80% of energy [15]. However, innovation is hindered by the lack of joined up approach on water reuse at the household level household level, including showering products like shampoos or body soaps optimized for such technologies.

Developments in membrane filtration technologies, used in seawater desalination and industrial water treatment, are driving the innovation of water reuse at the city level; much of the water reuse deployment is happening in cities. The routes to market for water reuse systems are complex and there is a lack of clear conformance to standards that could help build public confidence in the products.

Unlike water-efficient products, many water reuse systems are not 'plug and play' replacements for existing appliances, making the retrofitting of water reuse systems in existing homes complex.

Non-potable water reuse can be used in the home for toilet flushing, external irrigation and laundry.

Water reuse products on the market are most suited for new build homes where changes from traditional designs and layout can be built in.

However, housing developers do not typically offer the option for water reuse as there is low demand from prospective homeowners due to lack of awareness. These combine to create a disincentive to innovation in household-scale water reuse systems for consumer product innovators.

The benefits of water reuse are shared by everyone. Investment in creating the market and in the innovation of new solutions ideally needs both public and private funding. Many countries are providing innovation funding to the water sector.

The UK has a US$380 million innovation fund to grow the water sector's capacity to innovate, enabling it to better meet the evolving needs of customers, society and the environment [16]. Such funds help stimulate innovation in water reuse solutions.

Whilst technological development in recent years has resulted in substantial advancements, many are difficult to retrofit into existing homes, either because of lack of space, inconvenience during the retrofit, or the scale and cost of retrofits required for the plumbing systems [74].

Technological innovation often overlooks the needs of the poor as the early adoption is driven mostly by the purchasing power of the richer consumers [75]. However, collaborative measures—such as the Chilean Ministry of Housing efforts in integrating water reuse technologies in social housing developments (Condominio El Bosque, Santiago, Chile) and the Isla Urbana rain capture initiative in Mexico City—show that innovation in water reuse can also serve the needs from vulnerable groups [70].

KEY DRIVERS FOR WATER REUSE

To meet global water challenges, water reuse, together with other demand management techniques, contributes to delivering a circular water economy.

Several drivers influence water reuse practices.

Consumer-led approaches to reduce reliance on municipal water systems are successful in water stressed regions or where customers receive intermittent water supply. Such systems are prevalent in the Global South to optimize water and economic resources. One example is the widespread adoption of rainwater harvesting systems in Mexico City, though this is heavily subsidized.

In less water-scarce areas, water reuse is adopted through top-down government led approaches and policy. It is important to frame the need to adopt more sustainable water systems through the challenges of reaching infrastructure limits and the drive to achieve net-zero carbon.

Currently, the relatively low cost of water to the consumer and generally high costs of water reuse technology has not stimulated widespread adoption of household water reuse. However, water charges are increasing, and innovation is reducing the cost of water reuse systems.

Cape Town's brink of 'Day Zero' forced an implementation increase of 390% in combined water and wastewater tariffs additionally to consumption reductions [17].

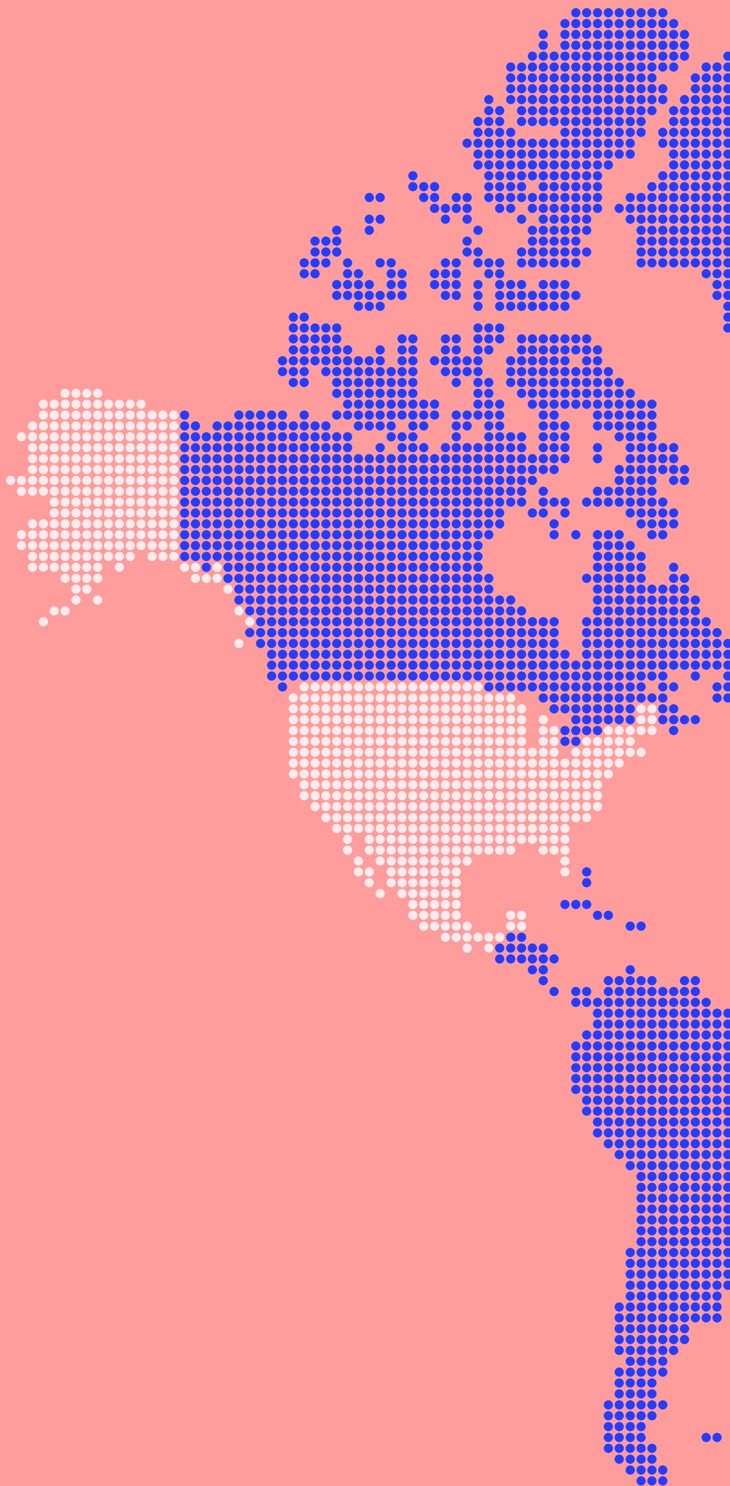
Water reuse closes the loop between water supply and sanitation, providing an alternative water source. This reduces the reliance on fresh water supplies and demonstrates the principles of a circular economy. Water reuse technology can be implemented at the scale appropriate to a city's needs and particular context.

Possible trade-offs with water security and carbon impacts of the particular choice of water reuse technology need to be considered.

Alternative water sources account for more than half of Singapore's water use: rainwater collection (20%), water reuse (30%) and desalination (10%). The cost of water to consumers includes cost of production, supply and a water conservation tax [67].

Israel has invested in reclaimed water infrastructure to maintain high water quality. This has enabled 90% of wastewater to be reused for non-potable end uses. The reclaimed water is supplied at lower costs than potable water. [68] [69].

Opportunities to combine renewable energy with water reuse will mitigate any negative carbon impacts.



FOCUS GEOGRAPHIES

The following pages explore four key geographies, China, India, Mexico, and the USA, that demonstrate the potential for water reuse. They were selected for their range of drivers and their potential for adoption of water reuse.

WATER AVAILABILITY CUBIC METERS PER CAPITA

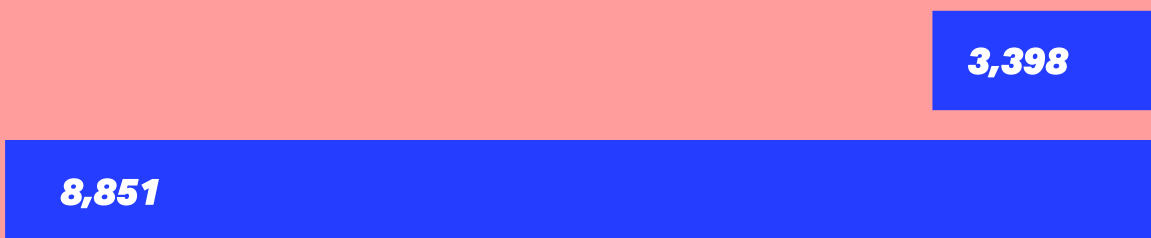
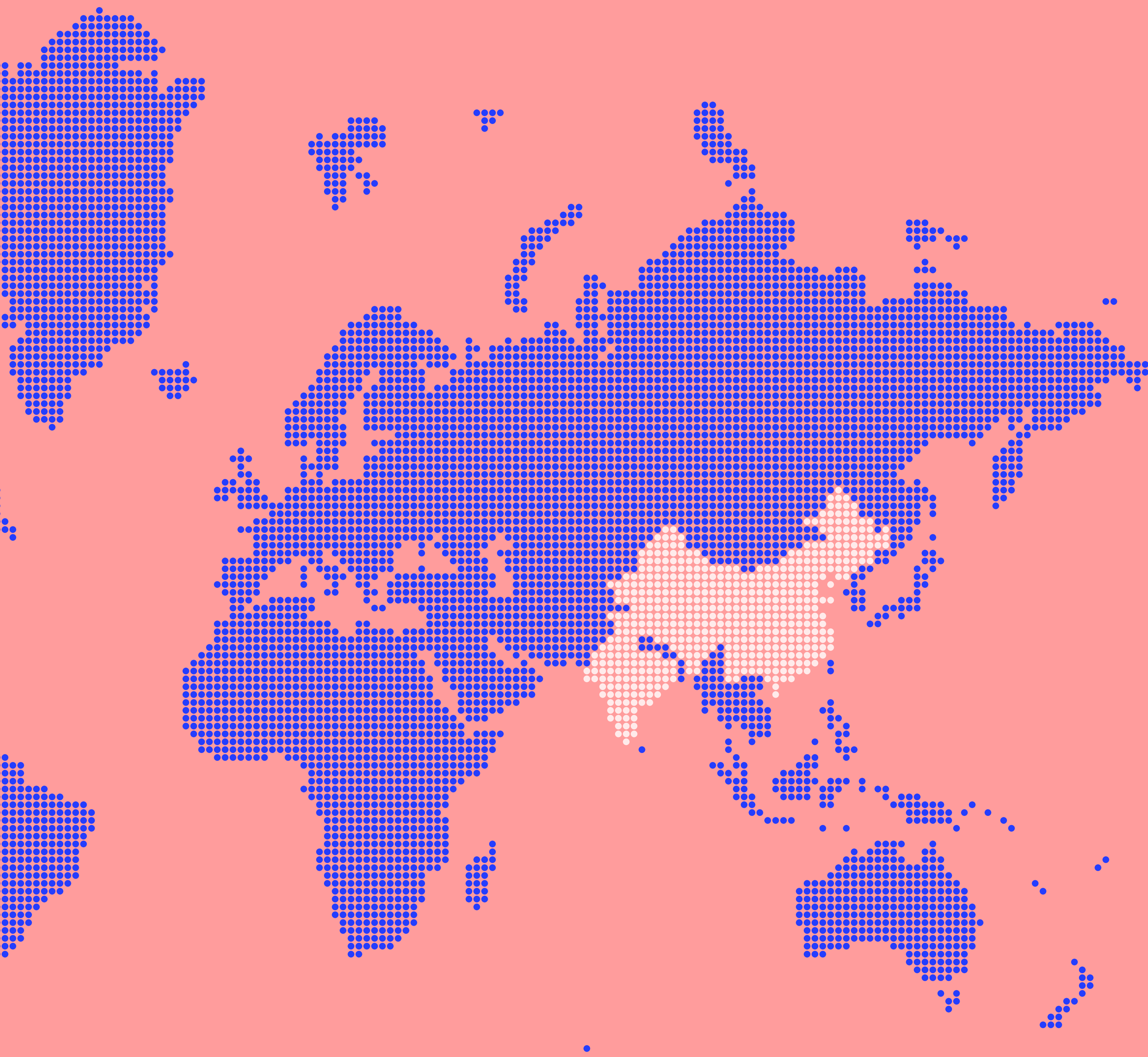
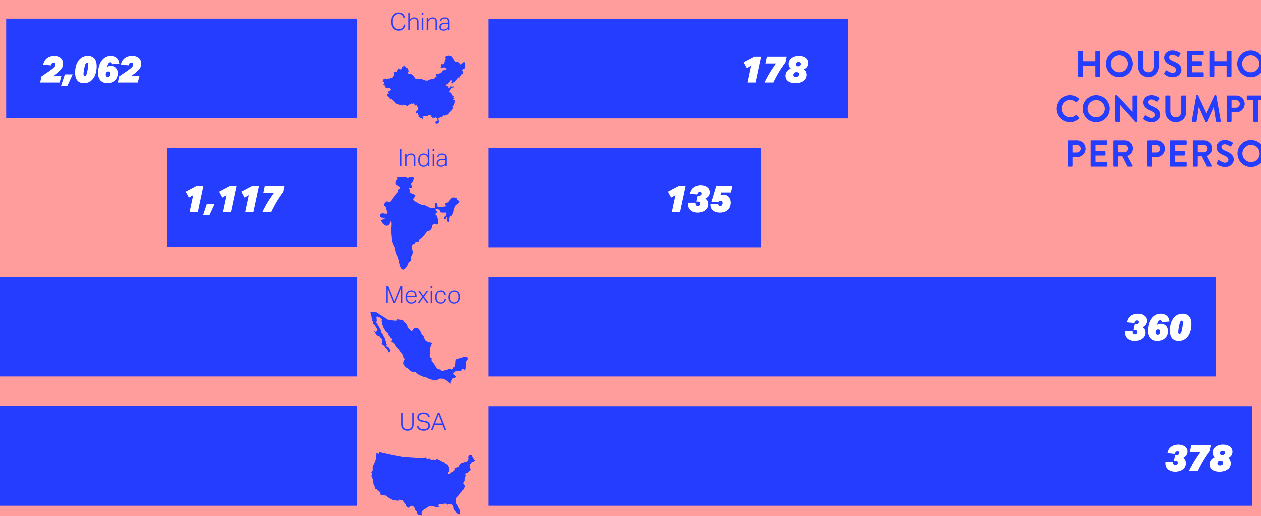


Figure 5: Summary of Water Consumption and Water Supply Infrastructure





HOUSEHOLD WATER CONSUMPTION LITERS PER PERSON PER DAY

CHINA

China has experienced rapid population growth and urbanization, and is now home to eight out of 33 of the world's megacities. The pressures of urbanization have reduced fresh water availability and quality.

In China, there is spatial and temporal variability in rainfall resulting in regional water stress [18]. Over-exploitation of groundwater is resulting in depleted groundwater sources. Untreated or inadequately treated municipal wastewater, industrial effluents and agricultural runoff has caused significant pollution of fresh water.

The Chinese Government recognizes water reuse as a potential solution to these challenges and in sustaining water supply to its people. Globally, it currently has the largest total volume of wastewater, particularly non-treated wastewater, being reused. This is mostly used for non-potable uses, such as agricultural irrigation, ornamental/recreational facilities and miscellaneous uses in urban areas [19].

Centralized water reuse systems have been the preferred option when serving urban areas. This is due to the presence of existing infrastructure, skilled process operators and the ability to adapt water quality to different uses. There are a few decentralized greywater reuse projects in university campuses and residential buildings, e.g. Beijing Normal University, but initial cost and lack of knowledge and experience of their operation has resulted in a low rate of adoption.

The Sponge City Program pilot, launched in 2014, in thirty cities across the country, supported by multiple ministries, with the goal to absorb and reuse 60% of rainwater. The project embraces regional flexibility and coordination to build sustainable, climate-resilient cities and urban water management systems [20]. The 2021-2025 National Five-Year Plan has a 15% target for water reuse rate nationally and is increasing investment in reclaimed water projects.

In 2003, greywater reuse systems in Beijing were mandated in all new-build hotels over 20,000 m² and sports centers, government buildings, universities and, institutes with a construction area of over 30,000 m². Currently, 50% of decentralized water recycling systems in Beijing are being used [21].

China has made good progress in developing water reuse technology, adapted from desalination membrane technologies.

Current technologies are mostly developed for the municipal building and neighborhood scale with a lack of domestic reuse technologies for the household scale.

Reuse technologies are relatively less expensive in China compared with other countries. However, the high cost for retrofitting existing homes to accommodate reuse technologies remains a major barrier. The lack of financial incentives for utilities and residents, and lack of trained operators to maintain systems following implementation are also significant barriers to wider adoption.

TRIPLE WATER SUPPLY SYSTEM

Seawater and greywater supply.

Hong Kong has adopted seawater flushing for 80% of its 7.5 million inhabitants. The Hong Kong International Airport combines fresh water, a seawater supply system (consisting of 20-30% seawater) and greywater reuse into a low-energy consumption and low-cost triple water supply system.

The applicability of this the system has reduced the fresh water demand for the airport by 52% [22].

1-2-1 PROJECT

Rainwater harvesting to meet growing demand.

There has been a successful pilot project '1-2-1' in Gansu, China, where provincial government, financial grants and rainwater collection methods were key tools in the implementation of a rainwater harvesting scheme.

The name refers to each household acquiring:

1 rainwater catchment area,

2 underground water tanks (30-50m^2) and

1 piece of land (670m^2).

This benefited over 2 million people in arid region of Gansu over a period of 10 years [23].

SPONGE CITY PROGRAM

A suite of bespoke solutions for cities.

An urban water management program put forward in 2014 in order to relieve the flood inundations and water shortage situation. The goal is to absorb and reuse 60% of rainwater in urban areas. Thirty cities were selected by the scheme.

The government provided funding towards the design of the systems and invested in educational campaigns, providing successful implementation of rainwater harvesting schemes at the household level. The geographic, hydrologic, economical characteristics of the thirty cities vary from each other, therefore the program plan and implementations were different across the cities [24].

Establishing shared key performance indicators related to water reuse would enable the Government and siloed organizations to align action towards, and achieve, the targets of the National Five-Year Plan. Clear KPIs will help building the bridge between local government and developers, giving multiple stakeholders the tools to determine at what scale the deployment of water reuse innovation is appropriate to their specific local conditions.

Pilot projects have demonstrated that Government-backed incentives, providing financing incentives have unlocked implementation challenges in China. A centralized reclaimed water approach has been taken across the country. This should be coordinated with actors at the local level to enable more households to take advantages of water reuse.

INDIA

India is currently home to 1.36 billion people with over a third living in urban areas. The rapid pace of urbanization has exceeded that of infrastructure development, resulting in lack of basic amenities in peri-urban areas and the management of water resources and solid waste [25].

Currently, only 70 million Indian households have piped water supply, or about 36% of the national target. A national US$49 billion program will put piped water in all of India's 192 million rural homes – more than all the houses in the USA by 2024 [26].

Half of the annual precipitation falls in just 15 days [27], and requires large dams and reservoirs to ensure supply throughout the year. In addition, unregulated groundwater abstraction has led to declining groundwater levels by 61% between 2007 and 2017 [26]. International Water Management Institute (IWMI) predicts severe water scarcity in India by 2025 [28].

Only 6% of the water abstracted for use is for municipal purposes, with 89% abstracted for use in agriculture and 5% for use in Industries. Even though there is significant potential to improve water use efficiency in agriculture, it is likely to take time and water reuse will be needed to meet the service needs in the cities.

The policy and guiding frameworks in India recognize the need for wastewater recycling, and water recycling is a legal requirement for large institutional users of water such as industries, universities, housing complexes, and five-star hotels. However, little has been done in terms of developing and implementing regulations, policies, or guidance for household uses.

India has some examples of household water reuse in urban cities for flushing toilets (i.e. Pune City and Delhi) and efforts have increased to explore the feasibility of using treated municipal and industrial wastewater for gardening, irrigation, and even for potable uses.

However, there are several cases of lack of community trust in authorities, especially for water quality and health-related issues. There is also psychological aversion to water reuse and Indian society is culturally reluctant to reuse wastewater, which limits the potential of its growth in the country [29].

The water law in India is largely state based [30]. Fragmentation of the water sector leads to a limitation of data availability which impacts planning. There is a lack of coordination between various sectors responsible for water supply and wastewater management. An unclear division of responsibilities between different branches of administration contribute to this issue.

India faces many challenges to widespread adoption of water reuse, including at regional scale:

- Lack of existing network and treatment infrastructure
- High initial cost of municipal water reclamation
- Lack of local expertise in operation of water reclamation and reuse
- Perception that reusing treated wastewater would reduce revenue

And at household scale:

- High initial cost of household reuse systems
- Limited space for reuse technology in urban homes

Extensive pilot projects with private funding have been completed proving the successful business case for water reuse at the community level, for example, the SARASWATI initiative.

SARASWATI

Piloting successful decentralized systems.

This project was funded by the EU to evaluate existing decentralized wastewater treatment plants across India and piloting proven European technologies.

The framework for evaluation was based on technical-environmental evaluation and socio-economic evaluation. It was found that most decentralized sewage treatment plants were found in rural areas with cheaper land availability.

It also concluded that traditional governance in the water sector suffered from the fragmentation of institutions, excessive centralization and an unclear division of responsibilities between different branches of administration [31].

AWARENESS OF RAINWATER HARVESTING

Growing acceptability of water reuse.

At the household level, washing of clothes consumes the highest amount of water in Dhani Mohabbatpur village, at about 19.0% of the total consumption. This is followed by consumption in bathing (16%), domestication of livestock (15.3%), cleaning of house (14%), and washing of utensils (11%). On an average, less than 10% of the total water consumption in a household is used for drinking and cooking.

However, the awareness about rainwater harvesting in Dhani Mohabbatpur village is inadequate and only 12% households showed awareness about the rainwater harvesting technology.

The survey on adaptation of rainwater harvesting technology demonstrated that about 92% households are immediately ready to adopt the technology if the households are provided with government subsidies.

Discussion with villagers exhibited that about 17% households are willing to install the water harvesting structures if they are to personally invest in rainwater harvesting technology [32].

Given the size and development path in India, achieving scale is an urgency for water reuse innovations. Innovation in water reuse at the household level is required to reduce costs. The implementation of water reuse should be coordinated at the regional scale. Advancing successful pilot projects and the use of community-based platforms (schools, community groups, social media) will promote the acceptance and benefits of water reuse in growing cities.

The mass adoption of water reuse innovations require the technology to work ‘in the real world’. They must be simple to operate and allow for a degree of customization to account for local needs. Focus should also be placed on service innovation in water reuse, and not just should not be limited to product innovation, to meet customers’ needs [75].

MEXICO

Water stress in Mexico is not distributed evenly, with the north of the country being more water-stressed than the south. Most of the water used in Mexico is dedicated to irrigation and cattle raising. 14% of total water use in the country is dedicated to municipal use.

More than half of public water supplies come from aquifers. Of the country's 653 aquifers 16% are experiencing overexploitation, and 3% have saline intrusion [33].

Climate change is set to reduce precipitation in most of the country by 10% [34], and the impacts of this will be exacerbated by high levels of poverty and inequality, with the poor disproportionately affected by the consequences. As a result, rainwater harvesting is seen as a viable option to solve water scarcity problems, especially in the capital where floods are a common occurrence. Such rainwater harvesting systems have been showcased by Isla Urbana [35].

There is a vast difference in how water is used domestically across Mexico. The country is the world's largest consumer of bottled water [36]. In some regions including in the capital, Mexico City, bottled water is used for cooking and even bathing [37]. Some residents claim that the piped water into their homes is discolored or has a foul odor, while the authorities state that the water is clean [38]. There is evident mistrust in the use of piped water into homes in several parts of the country.

Many residents in Mexico who do not have a piped water connection receive water from trucks (known as a 'pipa') that deliver water periodically. This is common in unplanned neighborhoods or neighborhoods that were built with no permits.

The pipas can often lead to social tension between communities who have to fight for the water and can have knock-on social impacts such as women not being able to leave home to seek employment due to the irregular nature of the truck water delivery [39].

Due to the growing population in cities, it is common for urban watersheds to import water from rural watersheds. This has caused a lot of tension between the urban, rural and even indigenous populations, and has left many rural populations with limited water access [40]. Consequently, water reuse in the home is a common practice and happens in the form of using irrigation water for toilet flushing or washing clothes.

In 2020, the Environment Secretary for Mexico City launched 'Cosechar la Lluvia', a program aimed at installing small-scale rainwater harvesting systems in homes.

The aim is to address the imbalance of water access across the city. The city has collaborated with Isla Urbana to install 100,000 systems during the secretary's six-year term at a cost of around US$11 million in 2019 [41].

The National Water Program 2020-2024 (Programa Nacional Hídrico 2020-2024) listed five priority objectives, one of which is to "preserve the integrity of the water cycle to guarantee the hydrological services provided by basins and aquifers". To achieve this, the government's strategy aims to maintain rainwater harvesting systems to avoid the involvement of third parties [42].

There is no mention of household greywater reuse as part of the national plan. Although the National Water Program exists, it is poorly coordinated for water reuse.

COSECHAR LA LLUVIA

Subsidies to encourage the uptake of rainwater harvesting.

In 2020, the Environment Secretary for Mexico City launched 'Cosechar la Lluvia', a program aimed at installing small-scale rainwater harvesting systems in homes.

The aim is to address the imbalance of water access across the city. The city has collaborated with Isla Urbana to install 100,000 systems during the secretary's six-year term at a cost of around US$11 million in 2019 [41].

ISLA URBANA RAINWATER HARVESTING

Rainwater harvesting to cut carbon emissions.

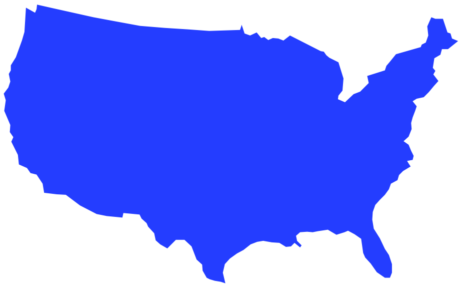
Manufacturers such as Isla Urbana have been chosen as collaborators by the Mexico City Environment Secretary (SEDEMA) for the mass rollout of such systems [41].

This is additionally an opportunity to reduce the city's greenhouse gas emissions – where much of the water network is pumped to overcome the city's topography as well as high leakage percentages in the system. The Lerma-Cutzmala system imports 18% of the city's water from other basins, however, consumes 65.5% of the electricity required in providing water [43].

The successful roll-out of rainwater harvesting systems, provides a model for local and national authorities. On this basis, collaborative work shall expand the innovation scope towards establishing policies and regulations to promote and co-implement other water reuse technologies, to mitigate periods of low rainfall.

Integration of rainwater harvesting solutions with other water reuse technologies, and thus mitigate will further enhance the security of water supply at local and regional levels. The technologies should diversify beyond rainwater in order to build resilience for periods of drought.

UNITED STATES OF AMERICA



NASA reported one third of continental USA is experiencing at least a moderate level of drought [63]. Water infrastructure is extremely vulnerable to extreme weather and climate change.

The proportion of domestic water used for toilet flushing varies generally from 29% to 47%. The use of recycled water for household toilet flushing could significantly reduce potable water requirements. The amount of greywater produced from baths, showers and washbasins in the home is often of sufficient quantity to provide the necessary flushing volumes [45], [46] and [47].

The States of Florida and California's depleting water resource and environmental concerns led to the inclusion of dual reticulation schemes as part of their water strategy [48]. On the Eastern Coast of the USA, the ability to develop outside of sewered areas is the driver for local community scale recycling systems. Environmental concerns and longer-term sustainability issues are also a factor [49]. Water reuse on the Eastern Coast, is not driven by physical water scarcity but by over-capacity of sewer networks, stormwater management and climate change factors such as rising sea level and saltwater intrusions [50], [51].

As of 2017, an estimated US$18 billion investment in water reuse and desalination projects were in development in 17 states [52]. Almost 90% of all volume of water reuse in the USA occurs in just four states: Arizona, California, Florida, and Texas. California and Florida continue to be the two largest users of recycled (reclaimed) water.

While the largest use for recycled water in California is for agricultural use and for natural systems, Florida consumes more than 50% of all recycled water used just for urban reuse (landscape irrigation, golf courses). Both states also use reclaimed water for industrial reuse and ground water recharge [53]. In San Francisco, the local utilities provider is currently piloting solutions at several scales including for buildings and with industrial consumers like breweries.

States generally maintain primary regulatory authority in allocating and developing water resources. Some states have established programs to specifically address reuse, and some have incorporated water reuse into their existing programs [54].

Under the executive order signed in October 2020, the Water Cabinet will improve water infrastructure planning by promoting integrated planning and coordination for drinking water, wastewater, water reuse, water storage and delivery, and water resources management. They will also support and enhance workforce development to recruit, train, and retain water sector professionals [55].

Across the USA, water technology innovation clusters are producing new cost-effective technologies, creating jobs, and improving the quality of their water infrastructure.

These 'clusters' are groups of people from the private, public, and academic sectors who share information and resources to spur economic development in their own regions' water industries.

Water clusters most commonly fulfill their mission and are carried out throughout the country by the EPA. They are successful by supporting the development of new businesses, expanding products and services of existing businesses, hosting meetings and conferences, conducting outreach campaigns, providing funding opportunities, and organizing training events for members [56].

EFFECTIVE POLICY IMPLEMENTATION

Stimulating innovation.

One example of successful policy implementation in the USA and its acceleration for innovation pathways, is how the state of California implemented a loading order policy. This is where energy demands are met first by efficiency and demand response before new generation is considered.

These strong policies and targets have achieved success in reducing energy demand, making businesses more competitive and allowing consumers to save money while improving health and increasing comfort. Additionally, this has increased the pace of technological progress to achieve greenhouse gas reduction [57].

CREATING A MARKET FOR WATER REUSE

Lowering the cost to the end-user.

Systems change is enabled through water companies saving money, but also through the opportunity to make money by selling reclaimed wastewater.

USA municipalities such as California and Florida do this to great effect by selling reclaimed water at a significantly lower price than potable water.

This is used mainly in the agricultural sector and urban irrigation, 69%, with 16% used for industrial processes and 15% used for potable water consumption [54].

FUTURE PROOFING OUR HOMES

New-build policy for water reuse.

Within a building, it is usual that a 'dual plumbing' will be required for the conveyance of not-potable water. It is simple to include this additional pipework for water reuse during construction, but it is more difficult to retrofit the pipework for water reuse.

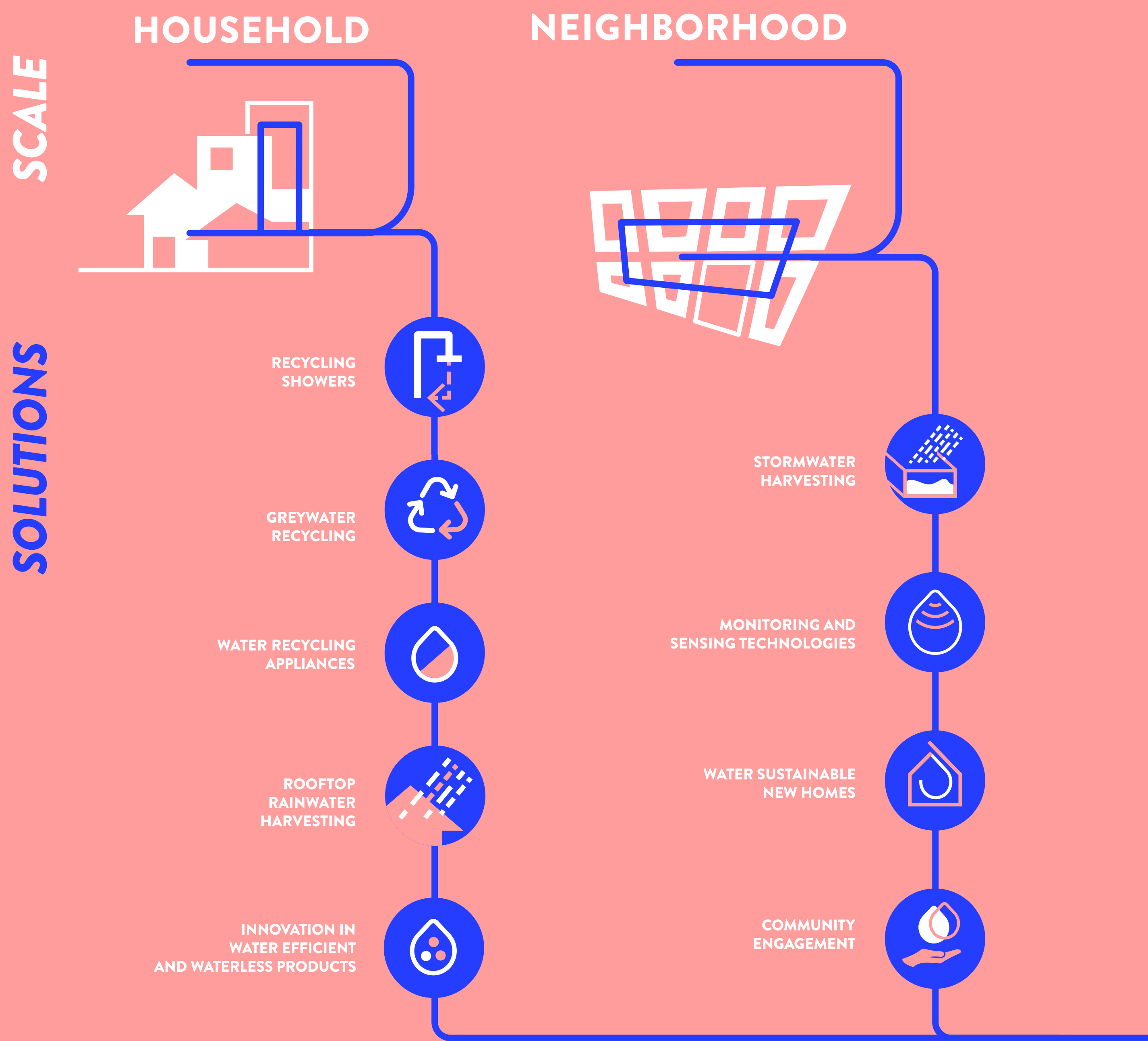
San Francisco is the first city in the USA to mandate newly contributed buildings (over 250,000 ft^2) to install onsite water reclamation systems [58].

Water reuse implementation has been successful in several states. These interventions can provide the inspiration and stimulus for neighboring states to adopt similar policies, creating a demand for such solutions.

Increasing peer to peer dialogue opportunities, demonstrative on site pilots, and investments in localized water strategies will help many cities in identifying the right scale to plan and implement water reuse solutions that are appropriate to their local context.

3. A SYSTEMIC APPROACH FOR MULTIPLE SCALES

The complexity of city water systems needs to be understood and exploited in multiple scales. Achieving the full potential of water reuse can be made through a systems approach.



This complexity must take into account how a household's water system is bound and influenced by its environment, expressed through different scales of water infrastructure in cities.

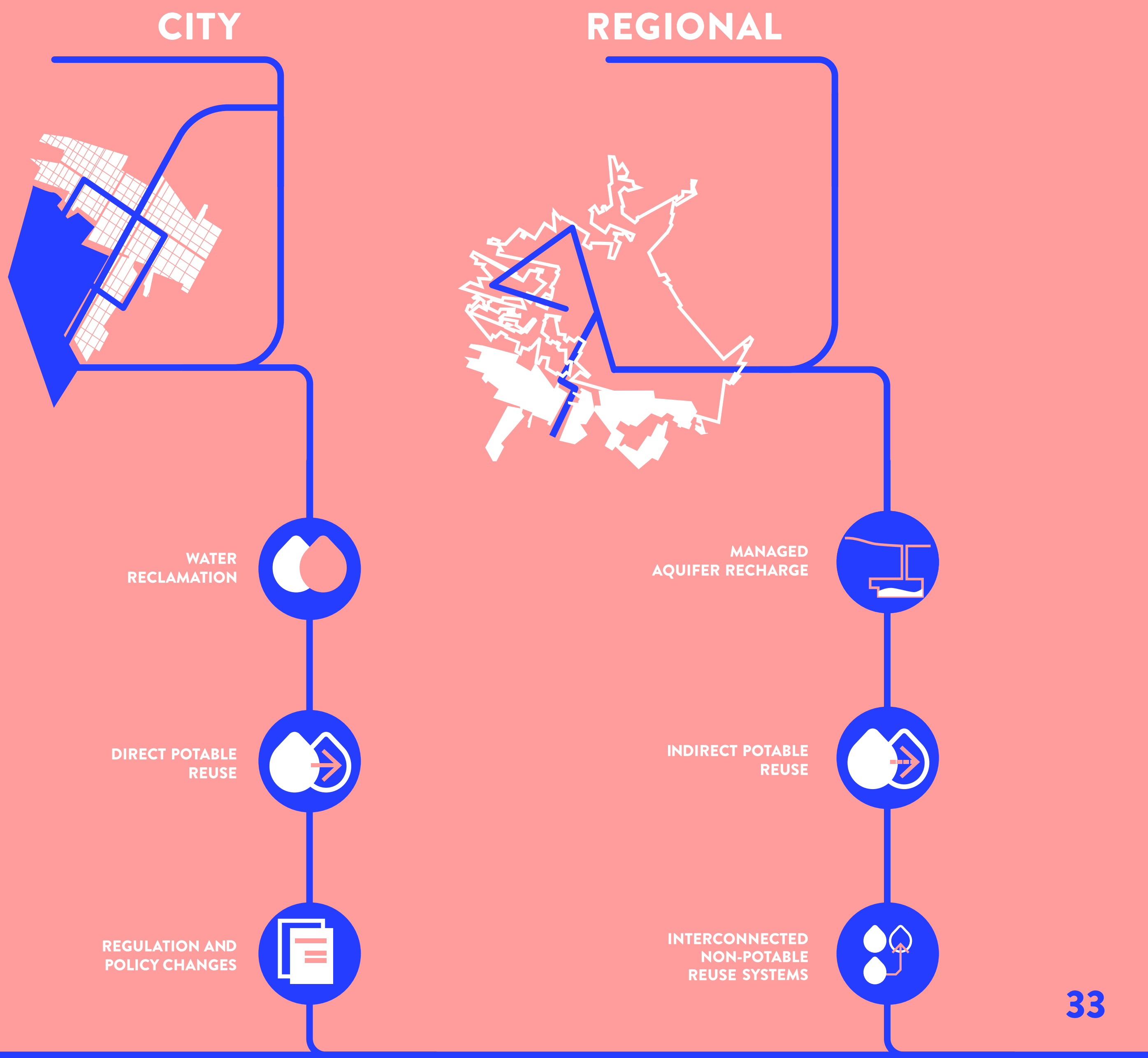
Circularity of water can operate at a household and neighborhood scale to city and regional systems, depending on the available infrastructure and technologies.

Efficiencies may be achieved through working at larger scales as well as through coordination between scales. Greywater harvesting systems, for instance, are often too big and expensive for a single apartment user however this same technology would be ideal for an entire apartment building. In general, the bigger the scale the more solutions fit into the natural water cycle and more hybrid solutions can be adopted.

The deployment of water reuse solutions should consider their impacts on the wider infrastructure. For instance, reducing a neighborhood's volume of wastewater generated can impact on sewer transport and treatment (as the organic and chemical loads will be more concentrated). The interception of rainwater using harvesting systems can reduce flows back to water courses as this water will be diverted by water reuse systems into the foul sewer system.

This multi-scale framework can help policy makers to identify the most appropriate entry point for their local context, depending on local policy, infrastructure coverage and local water stress conditions.

Figure 6: Scales of Water Reuse Solutions



HOUSEHOLD

Household reuse systems recycle water wholly within the home or from rainwater harvesting systems. This is usually implemented by the residents and can be incentivized by local government or utilities, to lower household running costs. Households offer a high potential for increased adoption of water reuse.

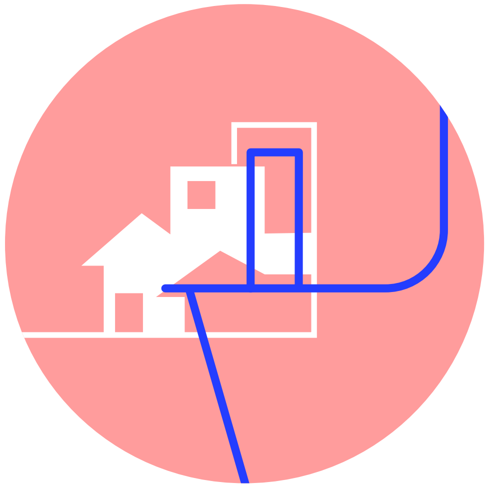
For instance, a household in Belgium has achieved a significant reduction (13lppd) in their potable water footprint through the use of greywater recycling and rainwater harvesting [79].

This is not surprising since the end-use appliances and products in the home remained unchanged, and thus did consumers' behaviours. Further systemic changes, especially at appliance level, at product level efficiency, and at behavioural data and reuse, can lead to more significant impact.

The widespread adoption of water reuse at the household scale will result in reduced flows within the local sewerage networks. This can be mitigated through better network monitoring and on-demand sewer flushing to ensure continued service. Solutions, such as automatic sewer flushing systems, are already available with that can be used to lessen the impact of reduced flows resulting from widespread household water reuse [76].

ACTORS OF CHANGE

- Technology and product developers
- Retailers
- Water utilities
- City governments



RECYCLING SHOWERS

Showers can use up to 100 liters of water for a ten-minute shower.

Water recycling showers use a basin and a pump to reuse the water while showering. The technology reduces the use of potable water and energy consumption for water heating. There is technology on the market that saves around 90% of water and 80% of energy per day.

WATER RECYCLING APPLIANCES

A dishwasher that captures the final rinse of the previous cycle, filtering it clean, and storing it in a small holding tank on the side of the machine. The water is then used to pre-rinse the next cycle and used to finish the wash [59].

INNOVATION IN WATERLESS AND WATER EFFICIENT PRODUCTS

Innovation opportunities especially lie in new ranges of products and consumables that can help enhance water-purification in combination with emerging water-recycling appliances and showers.

These can have a substantial impact in minimizing total water treatment requirements and energy usage for water reuse.

GREYWATER RECYCLING

The reuse of water from sinks, showers, and washing machines to use in purposes where potable quality water is not required for the operation, most commonly for toilet flushing.

There is often a form of treatment included in the local system (building or campus) which enables reuse of greywater without risk to sanitation or damage to appliances. New technologies enable this process to be localized at household level.

DIRECT POTABLE REUSE

The municipal wastewater can be treated using tertiary treatment, including disinfection and filtration of trace elements, to put back into potable water supplies. This solution has been used in some water scarce regions, such as Windhoek Namibia. As monitoring and treatment technologies improve, there will be greater potential for this solution.

NEIGHBORHOOD

Neighborhoods include residential buildings, campus developments, and the public realm in between. These may vary in size and type with separate units occupied by different residents. Here, reuse systems are assumed to reuse water wholly within the boundaries of the neighborhood.

At this scale, it is critical to have the co-operation of residents and the need for an agency (or agencies) who own or manage the neighborhood. The water reuse solutions at this scale require less individual action but an overall buy-into the process is critical.

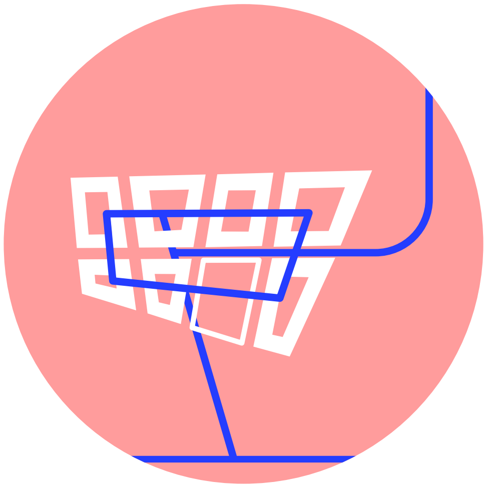
A lack of community interest or co-operation would hinder the implementation of water reuse at the neighborhood scale.

To gather interest from residents and real estate developers, the city governments and municipal water suppliers can play an active role in promoting water reuse, through incentives and grants, including training the service providers to maintain and operate such systems.

A successful trial of social housing development El Bosque, in Huechuraba, Chile, implemented greywater systems in 13 apartments, making water savings of 4,500 liters per day [70].

ACTORS OF CHANGE

- Technology and product developers
- Housing developers
- Water utilities
- City planners



STORMWATER HARVESTING

Capturing and reusing stormwater can not only meet some of the non-potable demands within the homes, but also help reduce the increase in runoff from the urban fabric. The captured water will require use of treatment to remove organic and inorganic pollutants before putting into supply. There will also be a need for non-potable water supply pipe network to be installed in the neighborhood.

COMMUNITY ENGAGEMENT

Awareness campaigns can help to promote water reuse as an accepted behavior. This can be through multiple mediums such as traditional and social media, podcasts and demonstration. Awareness campaigns should focus on the issue, move potential reuse supporters from interest to action and track success of social norming through key metrics.

This solution can be employed at neighborhood or city scale.

MONITORING AND SENSING TECHNOLOGIES

Monitoring and sensing technology can be used to manage demand and promote efficient use of water resources. Smart meters provide consumers with real time data of their water consumption. Smart meters help customers manage their bills effectively and leads to reduced use and opting for efficient appliances.

This solution can be employed at household, neighborhood or city scale.

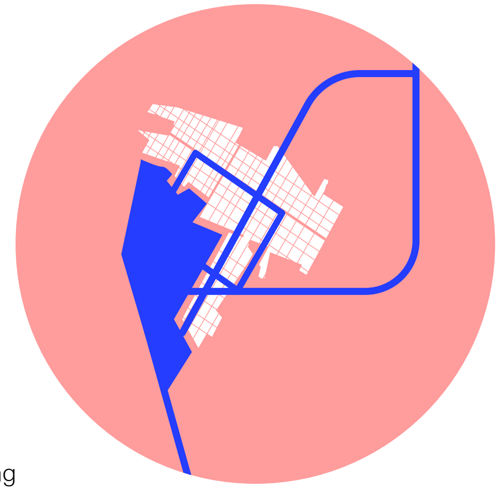
WATER SUSTAINABLE NEW HOMES

The delivery of new homes that utilize water reuse to deliver sustainable water use and meet highest sustainability rating will be key to normalizing water reuse.

City planners and housing developers will have a critical role in delivering such homes.

At this scale, several housing units can share technologies that would otherwise be too expensive if used separately.

CITY



Cities are much larger spatial units and may comprise many neighborhoods, as well as non-residential uses.

At the city scale, water can come from several sources including treated wastewater from a sewage treatment plant, or from seawater. Water supply at this scale is usually managed by a water utility, local government, or water service provider and the water reuse at this scale reduces fresh water demands from residential and non-residential users.

There are multiple users (agriculture or industry) with competing demands and sometimes surrounding cities benefit from reuse at this scale.

Many cities lack the infrastructure for the implementation of water reclamation. The development of new water reuse networks provide opportunities for economic development and job creation. These networks can be considered alongside other carbon positive systems such as heat networks to help reduce costs and infrastructure impacts.

In cities with limited drinking water and sanitation access, tranformational actions shall focus on enabling the 'leapfrogging' of those communities to appropriate and affordable infrastructure systems that enable high water efficiency from the beginning.

Water reclamation in Singapore contributes to 40% of its daily demand and its potable, surpassing the WHO's water standard [81].

ACTORS OF CHANGE

- Water utilities
- City government
- Public-private partnerships
- Water reuse potential as four scales
- Improving human adaptiveness and leveraging natural water cycle

WATER RECLAMATION

Blackwater (or treated effluent from wastewater treatment plants) and sea water have been used alternative sources of water for non-potable water supplies in some of the focus geographies. Water treatment and disinfection technologies will need to be employed to manage the risks to public health. The majority of these technologies are mature.

REGULATION AND POLICY CHANGES

Dual plumbing systems are required to supply both potable and reused water to a home. The separate systems prevent mixing of the two water supplies. Dual plumbing policies for new homes can accelerate adoption of water reuse.

Incentivizing investors with green finance initiatives will promote new ways of financing water reuse. Water companies and government can use tax and rebate incentives on water efficient appliances to promote adoption of water reuse.

DIRECT POTABLE REUSE

The municipal wastewater can be treated using tertiary treatment, including disinfection and filtration of trace elements, to put back into potable water supplies. This solution has been used in some water scarce regions, such as Windhoek Namibia. As monitoring and treatment technologies improve, there will be greater potential for this solution.

REGIONAL

The regional scale includes wider man-made and natural landscapes including urban areas, wetlands, canals, water courses, fresh water sources and water discharge.

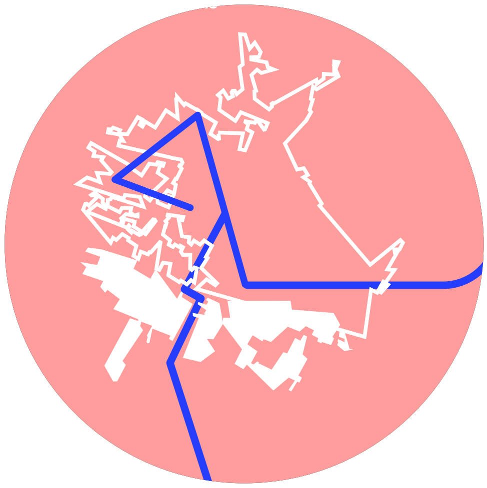
At this scale, man-made water systems are closely linked to natural hydrological and hydrogeological systems. Working at this scale, requires large scale hybrid solutions as well as strong links to national level water management infrastructure and policies.

The water ecosystem is sensitive to external influences. The widespread adoption of rainwater harvesting systems, could divert necessary water away from local streams or aquifers and discharge it further down the water system. City and national government bodies can provide maps showing areas where rainwater harvesting systems could be implemented without negatively effecting the local streams and rivers.

Although Israel's water reuse system is predominantly used for irrigation, around 10% is used for wider environmental purposes such as increasing river flow volume and fire suppression [77].

ACTORS OF CHANGE

- National and regional governments
- Water utilities
- Water Resource Management Authorities
- Corporations and Philanthropies



INTERCONNECTED NON-POTABLE REUSE SYSTEMS

Increasing the sources of non-potable water, extended beyond municipal wastewater such as from industrial processes, and food and beverage industries. Non-potable supplies from municipal wastewater can also be used by industry or agriculture reducing their abstraction of fresh water

MANAGED AQUIFER RECHARGE

A solution of groundwater management includes the managed recharge of aquifers, increasingly done through injection of tertiary treated wastewater from municipal supplies. This replenishes stressed aquifers that can be used for future abstraction for water supply.

INDIRECT POTABLE REUSE

Following tertiary treatment of wastewater, the treated water can be stored in water supply reservoirs and put back into potable supply. This closes the loop as majority of a city's water can be put back into supply reducing the fresh water abstraction.

4. LEADING SYSTEMS TRANSFORMATION

Water reuse provides the opportunity for systemic transformation of water use in homes. Integrating water circularity approaches with the planning and delivery of water systems, enables policy makers and those with transformative agency to identify appropriate water reuse solutions.

Governments can play a key role in building efficient and more resilient systems by investing in innovation and aligning their modus operandi towards value creation. Recognizing global urgencies associated with the climate and the priorities articulated by the SDGs, innovation in water reuse should not remain as a 'water sector' concern, but rather as an agenda that addresses simultaneously water stress, decarbonization and human outcomes.

Three 'levers for systems transformation' emerged from literature research and stakeholder contributions. Each lever can help explore opportunities and unblock challenges to the widespread adoption of water reuse.

They are:

Culture of Innovation and Partnerships

Awareness and Desirability

Adaptive Planning and Policy

The above levers create opportunities for various stakeholders through specific actions.

This approach challenges the common assumption that policy needs to change as a precondition, and sole requisite, to systemic change.

The action-oriented approach summarized in the three 'levers for systems transformation' rather focuses on the unique capacity of cities and regional governments of aligning stakeholders and creating opportunities to explore, learn and gather scientific knowledge and data. As a result, new policies will be based on localized evidence, state-of-the-art knowledge, and integrate tested ideas to accelerate their adoption at scale.

"the best outcomes lie at the intersection of desirability, feasibility, and viability".

50L Home Coalition

TRANSFORMATION THROUGH WATER REUSE

Figure 7: Key Levers for System Transformation through Water Reuse

When these levers are applied, they need to consider local cultural norms and a community's relationship with water. In different places, these might be most applicable at different scales (household, etc.). Solutions developed for water reuse must consider the condition and suitability of existing infrastructure as well as the various water stresses experienced.

CULTURE OF INNOVATION AND PARTNERSHIPS

The future of urban innovation has both climate change and systemic resilience in its core. The change to circularity needs an enabling environment that is dynamic and collaborative and adopts the climate agenda and human outcomes at its core. Achieving these positive actions requires all the different stakeholders to work together, and a social and decentralized leadership.

This can stimulate a culture of innovation that cuts across sectors of society: communities, technology innovators, water service providers, and public policy makers. In the public sector, a culture of innovation can lead to policies and regulations that promote private sector innovation, are adaptive to local needs, and collectively help improve service provision to the public.

The innovation pathway to the adoption of water reuse in homes and cities is reliant on widespread understanding of local water stress conditions, investment in technology, access to the technology, and its affordability for the intended audience. Innovative policies and financing can assist this enterprise. Innovation hubs can bring together social enterprises with technology innovators to develop and promote products and solutions. Diversity of thought, as well as sharing of ideas, can help to address shortcomings related to sector-limited tunnel vision.

The use of innovative approaches based on social engagement can raise awareness and nudge towards transformational changes in public perception and trust, and increasing the desirability of water reuse. These approaches could use low-tech methods, such as word of mouth and storytelling, or high-tech ones employing smart meters and water quality monitoring systems.

HOW TO TAKE ACTION

PUBLIC SECTOR

Invest in research and development of water reuse technology improvements and integration, localized knowledge on water stress, and a local climate agenda.

Set up an innovation hub to coordinate required technology research and development.

Create tax incentives, green tariffs, blended finance schemes, grants and / or low-interest loans.

PRIVATE SECTOR

Relevant trade associations for manufacturers of household water appliances and products to phase out less efficient offerings.

MULTI-STAKEHOLDER ACTION

Coordinate and promote collaboration to build understanding of the benefits of water reuse for different stakeholders.

Engage relevant stakeholders to form a common vision for water reuse at the intended scale.

WHAT CAN BE ACHIEVED?

Innovations in the water sector are 'de-siloed' and integrate water stress, climate mitigation and human outcomes as key drivers in their work.

A forward-looking water innovation agenda is shared by a diverse ecosystem that brings together public sector, academic and civil society and private sector organizations

Innovation in water reuse technology (at all scales) delivers improved performance at lower costs.

Collaborative partnerships have been formed and have implemented water reuse at scale.

Imaginative solutions enhance user experience, affordability, and desirability.

This leads to acceptance of water reuse and helps deliver capable workforce and sustainable financing.

ACTORS OF CHANGE

50L Home Coalition

National / regional governments

Water treatment technology manufacturers

Investors

Public-private partnership

Public-private-civil society organization partnership

AWARENESS AND DESIRABILITY

Transformative action in addressing water stresses can be only achieved by reshaping people's relationship with water. Improving the relationship of the public with water and the environment is key to their increased adoption of water reuse, together with experiencing the benefits of water reuse. Tailored messaging based on current and future needs will raise awareness of water reuse, taking into consideration broader social, cultural, economic, and institutional factors. This will have a greater chance of initiating a sustained behavioral change, which is key to systems transformation. Such messaging may help to encourage a reshape of people and policymakers' relationship with water and help to inspire behavioral and policy changes.

Example messages may be:

- For homeowners, highlighting how water reuse can help meet their unserved needs. This will be a key message in areas experiencing water stress or intermittent availability.
- For city authorities and water suppliers, highlighting how water reuse can help them provide service to more residents.
- For businesses and new service providers, highlighting the gap in the market.

The messaging should also aim to address the 'yuck factor' that surrounds water reuse and is present in many cultures. Successful tailored messaging will require a good foundation of research-based evidence of household water usage patterns as well as an understanding of the public's perception of water, local environmental issues, and water reuse.

Interventions must identify barriers to change, which are complex and may vary between different settings, e.g. between providers and consumers. Successful public – private – academic partnership is key. Making homeowners aware of the benefits of water reuse by itself will not lead to its widespread adoption. This can be evidenced by the fact that water reuse technology has been around for decades, but the adoption level is still very low in the focus geographies.

This impresses the fact that raising awareness is not enough and improving its desirability is a key factor to influence wider adoption of water reuse in homes, neighborhoods, or cities.

The factors affecting desirability, amongst others, include public perception, cultural reluctance, system costs, and financial benefits.

Demonstrator sites in day-to-day facilities such as gyms, public baths/pools, or office buildings using innovative water reuse solutions and promoting the technologies as lifestyle products, can not only educate people and policymakers but also increase their desirability. Integrating such technologies initially to high end 'desirable' residential and tourism projects can tangibly contribute to their adoption too.

The availability of financial incentives, reasonable financing that reduces the up-front costs or innovative service models that shift from purchase to service can also increase the desirability of these products.

HOW TO TAKE ACTION

PUBLIC SECTOR

Identify local needs, project or development areas to test innovations.

Create incentives for demonstrator projects and evaluate their impact in order to build a path to scaling up.

PRIVATE SECTOR

Implement demonstrator projects that are publicly accessible to further promote adoption.

MULTI-STAKEHOLDER ACTION

Collate relevant human behavior research through academia and develop plans for social norming of reuse.

Launch awareness campaigns using traditional and social media to communicate and educate the importance and benefits of addressing water stress and service gaps with focus on water reuse around environmental protection, water scarcity and resilience.

WHAT CAN BE ACHIEVED?

Organizations in the public and private sectors, as well as academia and civil society have a shared and holistic understanding on local needs associated with resource constraints (including water stress) as well as impacts of climate change.

Through collaborative approaches, a new generation of relevant and engaging ideas that address both climate and resilience challenges is increasingly adopted by citizens.

Coordinated messaging through public-private and NGO collaboration will create positive perceptions about the benefits and desirability of water reuse.

The widespread adoption of water reuse has demonstrated that it is safe, can save money, and improve sustainability and water security.

ACTORS OF CHANGE

50L Home Coalition

Product developers

City authorities

Water suppliers

ADAPTIVE PLANNING AND POLICY

Advancing policy, regulatory and industry frameworks is crucial for transforming household water use in the long term. Policy frameworks, however, must be updated and respond to a changing environment. Developing a culture of innovation and encouraging widespread awareness of local needs and solutions available will create a fertile ground for incremental adoption of innovative ideas that build quality of life for all. Generally, when water is physically scarce, governments recognize water and water reuse as a high priority. However, the review of focus geographies highlights that this is not always the case.

Creating a favorable environment for the development of appropriate policies and standards on water reuse is critical for its wider adoption. This requires a comprehensive understanding of water efficiency and reuse opportunities in all scales, and a strategic perspective on what solutions can create better climate and human outcomes. This includes the creation of local resilience and water strategies in coordination with national or state authorities, as well as enacting policies and regulations to promote and support water reuse. These instruments should consider local context, such as the need for more flexible standards [60], and provide clear guidance and a level playing field for all water service providers.

Planning and policy require a localized understanding of climate projections and active measures to prepare for an emerging future. Adaptive planning encompasses water resilience, recognizing opportunities to minimize the impact of shocks and to provide capacity to continue services in the face of systemic disruption or stresses.

Policies and / or regulations that mandate dual plumbing in new developments can accelerate the adoption of water reuse, whether it is at the household scale, neighborhood scale or city scale. This can provide a targeted and incremental approach to the adoption of water reuse.

Market forces can be harnessed through supporting policies, similar to renewable energy or electric vehicles, that incentivize the water reuse systems [61]. Enabling the private sector to rise to the challenge through regulatory and innovative financial incentives is key to enabling a robust environment for water reuse.

Based on examples from other sectors, such policy and targeted financial incentives, including novel tariffs, can accelerate the development of innovative products and solutions by the private sector that can meet the varying needs of the various geographies.

Effective enforcement of regulations, such as those for water quality, should be instituted. This can establish trust in the wider system that cascades to water reuse, as can be observed from case study examples in the USA and China.

HOW TO TAKE ACTION

PUBLIC SECTOR

Update Building Codes and Standards to include water reuse and requirements for dual plumbing, rainwater harvesting and water reuse in new homes and developments.

Propose mandatory labeling of water using products which includes the benefits of water reuse.

Conduct economic assessments and the creation of a 'market transformation program' to support the phasing out of less efficient products from the market – helping to creating an advantageous market for water reuse.

Adopt a water neutral policy where there is no net increase in fresh water use to meet demands from growing population within a city.

PRIVATE SECTOR

Housing developers to aim for best in class rating in their chosen sustainability rating scheme (e.g. BREEAM and LEED) and integrate water reuse systems into new homes.

ACTORS OF CHANGE

National governments
Water companies
Developers
Manufacturers

WHAT CAN BE ACHIEVED?

A locally relevant strategy that clearly sets out a city's (or region's) water and climate priorities and key investments. A clear strategy helps decision makers in all sectors, and citizens in general, to make better decisions on their opportunities to act.

Coordinated policy provides a coherent framework for water reuse to be deployed and helps build confidence to innovate new solutions. Policy supports the appropriate innovation through to the consumer level, enhancing the market for water reuse.

Dual plumbing and other measures enable resilience, making water reuse technologies a better fit for retrofitting homes, and future proofs buildings and homes. Established building codes direct performance standards on water reuse through dual plumbing and the use of rainwater and greywater guidance in new buildings and homes.

Although local planning policies can direct developers to achieve higher efficiency targets, it is more effective and quicker for building regulations to mandate higher efficiency and for the inclusion of rainwater and water reuse systems.

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