CIRCULAR AND RESILIENT URBAN WATER MANAGEMENT

A Compendium of Solutions for Local and Regional Governments

Morocco Urban Circular Water Resilience Initiative

ICLEI Local Governments for Sustainability

Circulars

Implemented by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Circular and resilient urban water management – A compendium of solutions for local and regional governments (Version 2)

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EXECUTIVE SUMMARY

This Compendium highlights 12 real-world initiatives that demonstrate how circular approaches to water can strengthen urban resilience, improve water security, and support sustainable development. The cases span three thematic chapters: (1) Decentralised, place-based, and participatory systems; (2) Urban integration and regenerative planning; and (3) Centralised circular systems and resource recovery.

They range from eco-districts and greenfield towns to industrial reuse and campus-scale pilots. Despite their diverse geographies and contexts, they share common threads: strong institutional coordination, long-term planning, early stakeholder engagement, supportive policy frameworks, and tailored business models that make circularity financially viable.

Case snapshots:

- **Sumida (Japan):** A district-wide rainwater harvesting network tied to disaster preparedness and civic pride.
- **eThekwini (South Africa):** Low-energy DEWATS systems integrated into informal settlements, co-led by the municipality and BORDA.
- **La Quebradora (Mexico City):** A multifunctional park that combines flood management, water capture, and public education.
- **Kénitra (Morocco):** A university-led initiative reusing treated wastewater to irrigate green areas within the campus
- **Shenzhen (China):** A Sponge City pilot that embeds nature-based solutions into fast-growing urban areas.
- **Googong (Australia):** A fully integrated water cycle in a new town using dual networks, rainwater harvesting, and water reuse.
- **Malmö (Sweden):** The Augustenborg eco-district retrofitted with green roofs, open stormwater systems, and biodiversity corridors.
- **Tunis North Lake (Tunisia):** A degraded wetland rehabilitated and redeveloped through real estate investment made in the form of a PPP.
- **Zenata (Morocco):** A planned eco-city where blue-green infrastructure supports aquifer recharge and climate resilience.
- **Santiago (Chile):** Biofactories transform wastewater into energy, clean water, and agricultural byproducts.
- **Surat (India):** A utility-industry partnership channels treated wastewater to textile plants, conserving freshwater.
- **Safi (Morocco):** A circularity model implemented by the phosphate industry combining seawater desalination and wastewater reuse in an industrial ecosystem.

Key lessons for Moroccan cities

Morocco faces pressing water stress, rapid urbanisation, and climate challenges. This compendium distils insights highly relevant to Moroccan cities:

- **Start early and integrate water planning:** Incorporating circular water strategies(e.g., reuse, blue-green urban infrastructure, nature-based solutions, rainwater harvesting, dual plumbing) from the outset in urban planning and expansion projects helps avoid future retrofits and stress on centralised infrastructure.
- **Create enabling regulatory environments:** All successful cases were backed by clear mandates, standards (e.g., for dual networks), and institutional support that de-risked investment.
- **Enable private investment with public oversight:** Many projects (Googong, Zenata, Safi, Surat) were financed by developers or industries as part of a negotiated package, while public authorities took on long-term operation or oversight.
- **Prioritise communication and education:** Public acceptance of reuse systems depends on clear messaging, school engagement, and visible infrastructure (Googong, Sumida, Santiago).
- **Design for multiple co-benefits:** Combining water reuse with green space, urban cooling, or education helps justify investment and increase impact (La Quebradora, Augustenborg, Zenata).
- **Invest in local capacity:** Municipalities and utilities that invested in staff training, stakeholder engagement, and institutional learning were more successful in implementation (Googong, eThekwini, Santiago).

Together, these cases show that circular urban water systems are not only technically feasible but can be economically viable and socially accepted—if supported by smart planning, governance, and financing frameworks. Moroccan cities, especially those undergoing new development or densification, can draw on this compendium as a practical resource to guide future investments in water resilience.

INTRODUCTION

Water is a critical resource for sustainable urban development. It's at the heart of many systems related to food, energy, health, and ecosystems. The importance of ensuring safe and clean water only increases in the context of the triple planetary crisis, rapid population growth, and accelerating urbanisation. At the same time, water security rests on the alignment of various levels of policy and governance, integrated planning, appropriate infrastructure development, and stakeholder participation.

This compendium is part of the *Urban Circular Water Resilience Initiative in Morocco – UCWRI*, led by ICLEI, and funded by the project *Circular Water Economy in Urban Areas – EccEauUrbain,* implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the German Agency for International Cooperation in Morocco, in partnership with the Moroccan Ministry of National Planning, Urban Development, Housing and Urban Policy (MATNUHPV). The EccEauUrbain project is funded by the German Federal Ministry for Economic Development and Cooperation (BMZ).

This compendium explores 12 case studies from around the world that unpack circular and resilient water interventions successfully implemented in contexts relevant to Moroccan cities.

Global water context

According to the United Nations reports, approximately 50% of the world's population faces severe water scarcity for at least one month each year, and nearly 26% live in countries where water supply is considered inadequate to meet needs. Africa and Asia are disproportionately impacted by droughts and flooding, with the majority of the approximately 2 billion people without sufficient water supply living in these regions.

Climate change is anticipated to worsen the current situation[1] with an increase in rainfall extremes that lead to drought and flooding. This is exacerbated by unsustainable water management practices, including over-extraction, inefficient agriculture, industrial pollution of waterways, and ineffective treatment and reuse solutions and infrastructure – challenges that are often intensified by rapid and unplanned urbanisation.

Vulnerable populations in lower-income countries are particularly at risk due to fragmented regulatory environments, ineffective infrastructure, and a lack of resilience built into their systems.

Addressing these vulnerabilities requires new models of urban development that integrate sustainable water practices from the outset. In this context, water circularity and resilience go hand in hand. The incorporation of circular water approaches into urban planning and infrastructure can provide a critical basis for cities to build resilience and better withstand increasing climate pressures.

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[1] https://unesdoc.unesco.org/ark:/48223/pf0000388950

Moroccan water context

Morocco is among the countries experiencing water scarcity, with its cities at the center of the crisis. The average Moroccan has access to only 606 m³ of water per year[2] – a figure projected to drop to 510 m³ by 2050[3] – well below the international threshold of 1,700 m³ per person per year, as defined by the Falkenmark Water Stress Indicator.

This decline is mainly driven by population growth, urban expansion, and reduced rainfall due to climate change. Urban areas face mounting pressures, including Day Zero risks, high water losses, insufficient financing for infrastructure, pollution, and poorly integrated water resource planning.

Recognizing these threats, Morocco has prioritised sustainable water management in line with national policies and royal directives. Guided by the National Program for Drinking Water Supply and Irrigation (PNAEPI) 2020–2027, the government has launched initiatives focusing on conservation, wastewater reuse, groundwater protection, and desalination, emphasizing cross-sector collaboration. Despite progress, challenges remain due to intensifying climate events, resource overuse, gaps in infrastructure and financing, and inadequate water management and governance – all of which must be urgently addressed.

Relevance of circular water solutions

Circular water solutions can play a key role in addressing Morocco's current water challenges and mitigating future water stress risks. They focus on conserving and reusing water, minimizing pollution, and regenerating ecosystems – while encouraging a rethinking of how water systems are planned, operated, and governed for long-term resilience.

The Moroccan government has increasingly incorporated circular water solutions into its national policy and legislative framework. Water management in the country is guided by national strategies and programs aimed at addressing scarcity and quality, with a recent emphasis on sustainable and efficient water use. A key document is the National Program for Drinking Water Supply and Irrigation (PNAEPI) 2020–2027, which represents the first phase of the National Water Plan (PNE) 2020–2050, a long-term strategy designed to improve water governance and address scarcity challenges. Supported by an implementation convention, this program has provided an important framework for sustainable and circular water initiatives.

Additionally, in early 2025, the Government of Morocco, together with multiple partners, initiated the development of the National Circular Economy Roadmap. This initiative aims to define an actionable pathway for Morocco's transition toward a circular economy. It builds on several sectoral frameworks, including the National Framework for the Promotion of Sustainable Consumption and Production, the Ten-Year Action Plan for Agriculture and Agri-Food, and the Ten-Year Action Plan for Eco-Construction and Sustainable Buildings.

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[2] https://www.equipement.gov.ma/eau/documentation/Documents/le%20secteur%20de%20l%27eau%20au%20maroc%202023.pdf

[3] https://documents1.worldbank.org/curated/en/299131516806648462/pdf/122698-FRENCH-v2Annexes-Sections-2-4-FR.pdf

Together, these efforts highlight the priority that Morocco has placed on transitioning toward a more circular economy across water and other sectors. While greater integration across the various plans, strategies, and regulatory frameworks remains essential to unlock the full potential of circular and resilient urban water solutions, these initiatives have already laid important groundwork, creating enabling conditions and momentum for many projects to move forward.

Project background

The *Urban Circular Water Resilience Initiative in Morocco – UCWRI,* led by ICLEI, is funded by the project *Circular Water Economy in Urban Areas – EccEauUrbain*, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, in partnership with the Moroccan Ministry of National Territorial Planning, Urban Development, Housing and Urban Policy (MATNUHPV). The EccEauUrbain project addresses the challenges related to urban resilience by promoting circular approaches to water management in urban areas and by proposing guidelines on the structural integration of the water sector into urban planning and development.

The UCWRI initiative contributes to these objectives by strengthening urban water resilience in Morocco, through the principles of the circular economy. It promotes a multi-stakeholder approach to address water scarcity, water quality issues, and ecosystem degradation. Its main activities consist of building the capacities of civil society actors and public authorities, promoting international city-to-city peer learning, and creating multi-stakeholder collaborative platforms at the local level.

A key output is the **Compendium of Solutions for Local and Regional Governments**, which features 12 case studies of best practices from Morocco and abroad. These examples showcase technical, policy, financial, and environmental aspects of circular water management. The Compendium is structured around a common analytical framework to ensure relevance and comparability, especially for Moroccan stakeholders. Through this document, local actos can identify and adopt sustainable, replicable circular water solutions that respond to both global as well as local urban challenges.

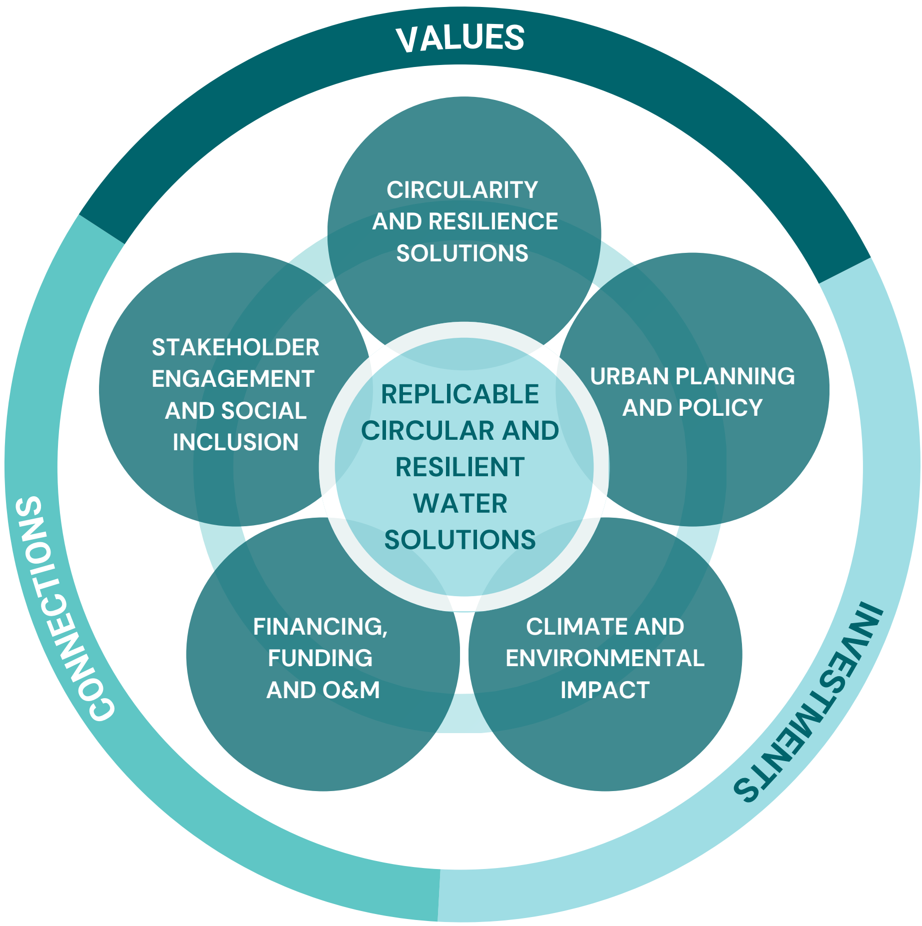
Structure of the compendium

Each case in the compendium follows a common analytical framework, structured around **five dimensions** that allow for clear comparison and practical insights:

1. **Circularity and resilience solutions:** Technical and infrastructural measures enabling water reuse, resource recovery, and adaptive management.
2. **Urban planning and policy:** Timeline of regulatory and planning instruments that supported project implementation, including key policies and strategies.
3. **Climate and environmental impact:** Contributions to mitigation, adaptation, ecosystem restoration, and other environmental benefits.
4. **Financing, funding, and O&M:** Investment models, operational approaches, and cost-benefit considerations ensuring long-term sustainability.
5. **Stakeholder engagement and social inclusion:** Participation of communities, institutions, and other stakeholders throughout planning, implementation, and operation.

Additionally, each case includes sections on:
(i) **Contributors to Success**, assessed across the framework of **Values, Connections**, and **Investments**, and
(ii) **Replicability**, highlighting how the approach can be adapted to other contexts in Morocco and beyond.

Figure 1: Analytical Framework and Contributors to Success



The compendium is organised into three chapters, each highlighting a key dimension of circular and resilient urban water management – from local-scale innovation and place-based interventions to large-scale system transformation. Together, the chapters illustrate a diverse range of approaches that can help cities enhance closed water loops, strengthen sustainability and resilience, and align urban growth with resource efficiency.

Each chapter also features at least one **Moroccan example**, demonstrating how the approaches discussed can be adapted and implemented in the national context.

Chapter 1: Decentralised, place-based and participatory systems

This chapter showcases small-scale, place-based and community-oriented solutions that demonstrate how decentralised systems can advance water circularity while fostering social inclusion and innovation. The **eThekwini (South Africa)** case highlights community-based decentralised wastewater treatment (DEWATS) as a sustainable sanitation and reuse model. **Sumida (Japan)** illustrates how widespread rainwater harvesting across public and private facilities enhances water security and civic engagement. **Mexico City - La Quebradora** integrates localised water-sensitive solutions with public amenities in Izatapalapa, creating urban spaces that combine flood management, water reuse, and community benefits. Demonstrating how decentralised, place-based approaches can be applied in Morocco, **Kénitra - Ibn Tofail University** showcases campus-scale wastewater treatment and reuse through a public–private partnership. These cases show how local-scale, participatory approaches can inspire circular water practices and inform their adaptation in diverse urban contexts, including Morocco.

Chapter 2: Urban integration and regenerative planning

This chapter focuses on integrating water systems into broader urban design, spatial planning, and ecological regeneration. **Shenzhen (China)** illustrates a city-wide sponge city approach, combining wetlands, canals, and infiltration systems to enhance resilience while supporting urban expansion. **Googong (Australia)** and **Malmö – Augustenborg (Sweden)** showcase how urban development (and redevelopment) can embed water reuse, stormwater management, and biodiversity into planning, creating multifunctional eco-districts. **Tunis North Lake (Tunisia)** demonstrates how regenerating a degraded coastal lagoon with water-sensitive practices can attract investments and drive sustainable urban redevelopment. In Morocco, **Casablanca – Zenata** provides an example of urban-scale water-sensitive planning, combining blue-green corridors, aquifer recharge, and climate-adapted design within a growing district. These cases provide guidance for Moroccan cities and beyond on using water as a structuring element for regenerative and resilient urban development.

Chapter 3: Centralised circular water systems and resource recovery

This chapter highlights large-scale water reuse, industrial applications, and circular resource recovery. **Santiago's Biofactories (Chile)** transform wastewater into energy, fertilisers, and reclaimed water, exemplifying the multi-resource potential of urban sewage. **Surat (India)** demonstrates industrial reuse of tertiary-treated wastewater to meet large-scale industrial demand while alleviating pressure on freshwater sources. In Morocco, **Safi** illustrates industrial-scale circular water management, combining desalination and wastewater reuse to secure resources for phosphate operations while reducing environmental impact. These cases exemplify the integration of circular economy principles into urban utilities, offering lessons on governance, financing, and the value of industrial reuse for water-scarce regions.

Methodology

Case data were gathered through desk research and ICLEI's global network of partners, local governments, and experts, with direct consultations conducted for selected cases.

Desk research involved the systematic review and analysis of grey literature, academic papers, official documents, policy reports, and project materials. In some cases, this was complemented by direct consultations with stakeholders actively involved in the initiatives. For other cases, ICLEI local offices working with the respective municipalities were consulted to ensure accuracy, contextual relevance, and completeness of the information. In instances where an abundance of literature was available and ICLEI did not have direct connections to the project or local officials, desk research was deemed sufficient.

Case study data collection details

Chapter	Case	Data source	Consultation
1: Decentralised, place-based and participatory systems	Sumida City: Rainwater Harvesting	Desk + Local consultation	ICLEI Japan Office, local government
	eThekwini: Decentralised Wastewater Treatment	Desk + Consultation	BORDA staff & former SA country director
	Mexico City: La Quebradora Park	Desk + Local consultation	ICLEI Mexico, Central American & Caribbean Secretariat
	Kénitra: Ibn Tofail University Wastewater Treatment Plant	Desk + Local consultation	University staff
2: Urban integration and regenerative planning	Shenzhen: Sponge City Program	Desk + Local consultation	ICLEI East Asia Secretariat, local experts
	Googong: Integrated Water Cycle	Desk research	
	Malmö: Ekostaden Augustenborg	Desk research	
	Tunis: North Lake Rehabilitation	Desk research + Local consultation	Al Buhaira Invest staff
	Zenata: Eco-City	Desk research + Local consultation	Local government staff
3: Centralised circular water systems and resource recovery	Santiago: Biofactorías	Desk research	
	Surat: Industrial Supply Initiative	Desk research	
	Safi: Circular Water Economy	Desk research + Local consultation	OCP Green Water team

List of acronyms

1. General concepts, systems, and operations

Wastewater and water systems

- WWTP – Wastewater Treatment Plant
- STP – Sewage Treatment Plant
- TTP – Tertiary Treatment Plant
- STEP – Wastewater Treatment Plant
- MBR – Membrane Bioreactor
- WRP – Water Recycling Plant
- RHS – Rainwater Harvesting System
- IWC – Integrated Water Cycle
- WSUD – Water-Sensitive Urban Design

Organisational or operational frameworks

- PPP – Public-Private Partnership
- CBO – Community-Based Organisation
- O&M – Operations and Maintenance
- EPC – Engineering, Procurement, and Construction
- EBITDA - Earnings Before Interest, Taxes, Depreciation, and Amortisation

2. Technical metrics and indicators

Water and wastewater quality

- BOD_5 / BOD5 – 5-day Biochemical Oxygen Demand
- COD – Chemical Oxygen Demand
- SS / TSS – Suspended Solids / Total Suspended Solids
- FC – Fecal Coliforms / E. coli

Water and wastewater volume

- L – Liter
- MLD – Million Liters per Day
- m^3/h – Cubic meters per hour
- Mm^3/year – Million cubic meters per year

Energy

- MMBtu – Million British Thermal Units
- MWh – Megawatt-Hour
- GJ – Gigajoule

Other treatment metrics

- tCO_2e – Tonnes of carbon dioxide equivalent
- UV – Ultraviolet (light disinfection)

3. General organisations and institutions

- NGO – Non-Governmental Organisation
- UN – United Nations
- UNIDO – United Nations Industrial Development Organisation
- EIB – European Investment Bank
- AFD – Agence française de développement
- RAMSAR – Convention on Wetlands of International Importance
- EBRD – European Bank for Reconstruction and Development
- ICLEI - Local Governments for Sustainability

4. Currency

- JPY – Japanese Yen
- EUR – Euro
- ZAR – South African Rand
- USD – United States Dollar
- MXN – Mexican Peso
- CNY – Chinese Yuan
- SEK – Swedish Krona
- TND – Tunisian Dinar
- MAD – Moroccan Dirham
- AUD – Australian Dollar

5. Project-specific organisations and acronyms

Durban, South Africa

- DEWATS – Decentralised Wastewater Treatment System(s)
- BORDA – Bremen Overseas Research & Development Association
- UKZN – University of KwaZulu-Natal

Mexico City, Mexico

- UNAM – National Autonomous University of Mexico

Shenzhen, China

- SCP – Sponge City Program
- LID – Low-Impact Development

Malmo, Sweden

- LIP – Local Investment Programme

- MKB – Malmö Kommunala Bostadsaktiebolag (Municipal Housing Company)
- SKR – Sveriges Kommuner och Regioner (Swedish Association of Local Authorities and Regions)

Surat, India

- SMC – Surat Municipal Corporation

Santiago, Chile

- EMOS – Municipal Company of Sanitation Works (Empresa Municipal de Obras Sanitarias)

Tunis, Tunisia

- SPLT – Société de Promotion du Lac de Tunis

Kenitra, Morocco

- ITU / ITU WWTP – Ibn Tofail University / Ibn Tofail University Wastewater Treatment Plant

Casablanca, Morocco

- CDG – Caisse de Dépôts et de Gestion (Morocco's Deposit and Management Fund)
- SAZ – Société d'Aménagement Zenata (Zenata Development Company)
- Lydec – Lyonnaise des Eaux de Casablanca (public water and electricity utility provider)

Googong, Australia

- NSW – New South Wales
- QPRC – Queanbeyan-Palerang Regional Council
- CIC – Canberra Investment Corporation

Safi, Morocco

- OCP – Office Chérifien des Phosphates
- RADEES – Autonomous Intermunicipal Water and Electricity Distribution Authority of Safi
- STEP – Wastewater Treatment Plant
- SRM-MS – Société Régionale Multiservices Marrakech-Safi (Regional Multiservice Company)
- PNAEPI – National Program for Potable Water Supply and Irrigation (2020–2027)

Thematic areas

Quickly identify the case studies most relevant to you using our icon system, which highlights the key technical themes featured in each case.

Water systems and technologies

Rainwater harvesting and reuse: The collection of rainwater for future use, which most often includes a storage facility.

Stormwater management and flood mitigation: Management of rainwater runoff to prevent flooding and water quality issues.

Groundwater recharge: A process that sees surface water replenishing aquifers.

Decentralised wastewater treatment and reuse: Treating wastewater near the point that the wastewater is generated, and reusing it at the locality.

Centralised water recycling and reuse: Treating wastewater from multiple locations and sources at a centralised treatments facility, and then distributing the water for reuse.

Desalination and non-conventional supply: Conversion of sea water, and other types of water, into fresh water for irrigation or human consumption.

Nature-based and landscape integration

Green-blue infrastructure / nature based solutions: Mesh of natural and artificial features and infrastructure that is purposefully designed to provide environmental, social and economic benefits, such as wetlands, green roofs, bioswales, and urban forests).

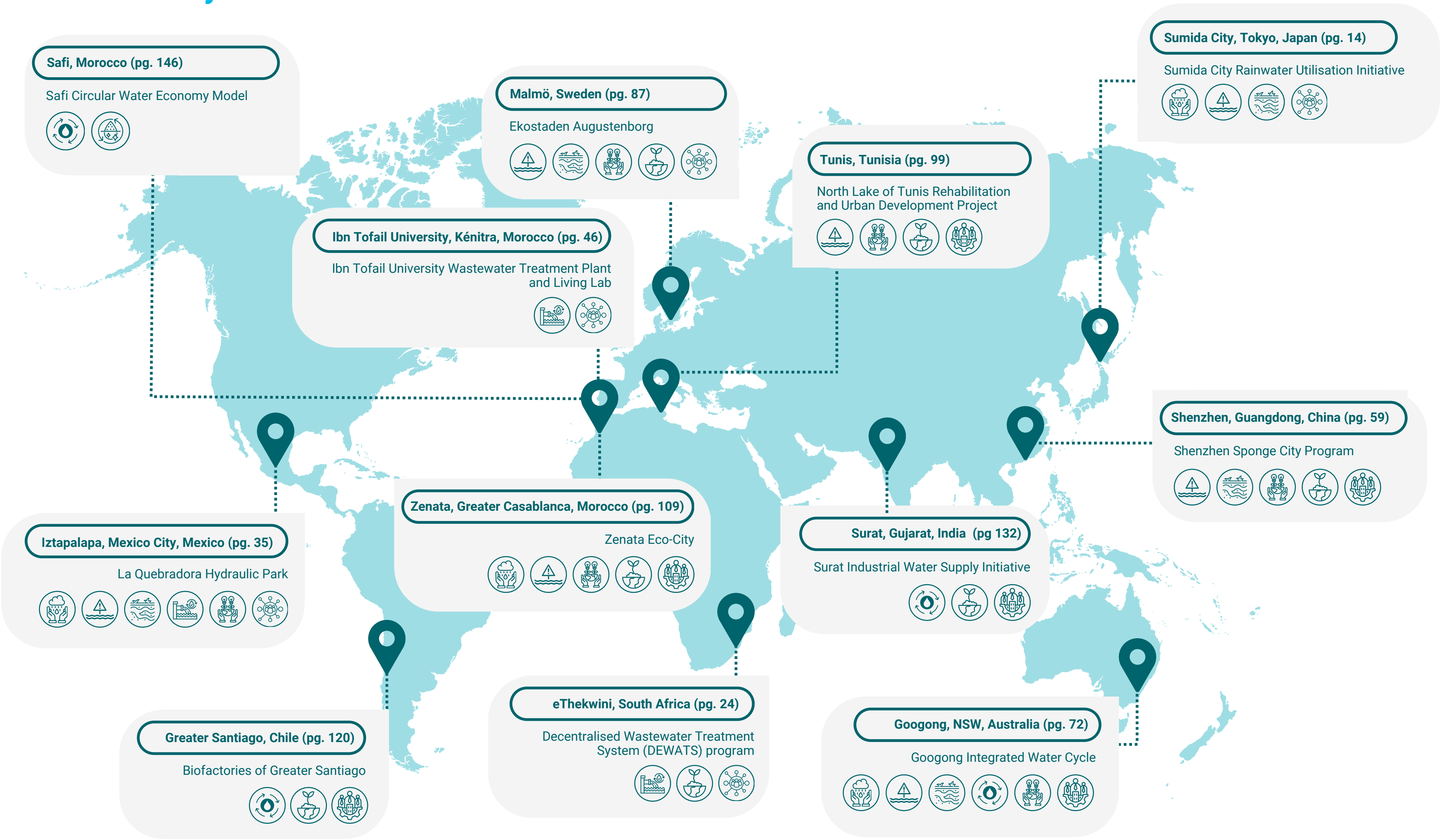
Urban ecosystems restoration and biodiversity: Circular or resilient water interventions that contribute to the restoration and regeneration of degraded urban ecosystems, enhancing biodiversity and ecosystem functions such as water filtration, retention, and habitat provision.

Planning, governance and engagement

Community co-creation and stewardship: Project approaches and practices that utilised collaboration and a shared sense of community and ownership to ensure long-term sustainability and relevance of water solutions.

Public-private and multilevel governance models: Water initiatives implemented through collaboration between public authorities, private actors, communities, and other key water stakeholders, across different levels of governance, to enable integrated and coordinated water management.

Case study locations



Chapter 1: Decentralised, place-based and participatory systems

SUMIDA CITY, TOKYO, JAPAN

- Rainwater harvesting and reuse
- Stormwater management and flood mitigation
- Groundwater recharge
- Community co-creation and stewardship

City overview

Population: 286,852 (2024)
Climate: Humid subtropical climate (Köppen Cfa)
Rainfall: 1,440 mm/year (high)
Water-related risks:

- **Flooding** due to low elevation, river overflow, and storm surges, aggravated by high-density urbanisation and low surface permeability, particularly during typhoons.
- **Water shortages** in periods of low rainfall due to reliance on upstream dams.

Case study overview

Initiative name: Sumida City Rainwater Utilisation Initiative
Location: Sumida City, Tokyo, Japan
Period: 1982–Present
Initiative type: Rainwater Harvesting & Reuse, Stormwater Management & Flood Mitigation
Scale of initiative: Neighborhood/District
Main project lead: Sumida City Government
Project objective: Enhance urban resilience in Sumida City through rainwater harvesting and sustainable water management to reduce flood risk and reliance on external water sources.

Main interventions

- **Public facilities:** Rainwater harvesting systems (RHS) installed in 49 public buildings (as of 2024), with notable examples:
  - Ryogoku Kokugikan Sumo Stadium collects rainwater from an 8,400 m² roof in a 1,000 m³ underground tank for toilet flushing and air conditioning.
  - Sumida City Hall collects 1,500 m³ of rainwater annually from a 5,035 m² roof for non-potable uses, including vehicle washing.
- **Private facilities:** Subsidised and mandatory processes for installing RHS in over 415 private buildings (as of 2024), including Tokyo Skytree (1,800-ton tank capacity, collected from a 3.6-hectare catchment area).
- **Community facilities:** Simple community RHS facilities (“Rojison”) installed in 20 locations, with a collective capacity of 246 m3, for daily use, firefighting, and emergency drinking water (as of 2024).
- **Permeable sidewalks** to support groundwater recharge.
- **Green roofs on public buildings** to manage rainwater, enhance insulation, preserve biodiversity, and reduce the urban heat island effect.

Main outcomes

- **Enhanced flood resilience:** Peak runoff was reduced by 15% through RHS, water retention, and storage.
- **Local water supply:** Over 10,000 m³ of rainwater is harvested and utilised across Sumida City annually, reducing water supply costs and dependency on large-scale water infrastructure.
- **Improved disaster preparedness:** Facilities like "Rojison" ensure access to water in emergencies.
- **Urban environmental benefits:** Additional green space helped to reduce average temperatures.
- **Restoration of the urban water cycle:** Permeable surfaces led to increased groundwater recharge rates.

Project cost

- **Community-level "Rojison" (including water tank and hand pump):** JPY 2–9 million (EUR 12,175–55,235) (2019).
- **Rainwater tank (household/public facilities):** Up to JPY 100,000 (EUR 613) per 200 L tank, including installation (2019).

Project

Context

Sumida City, located in eastern Tokyo, has historically faced water shortages and flood risks because of dense urbanisation and low elevation. In 1981, urban flooding brought catastrophic flooding to the region, causing extensive damage and leaving residents without drinking water for weeks. This prompted the city's Director of Urban Affairs to propose decentralised rainwater storage under buildings, serving as "mini-dams". These decentralised systems would improve local flood resilience, reduce dependency on external water sources, and eliminate the need for controversial, large-scale, and high-cost gray infrastructure.

Project description

Launched in 1982, the Sumida City Rainwater Utilisation Initiative sought to address the dual challenges of water scarcity and flooding through RHS in both public and private buildings. The initiative began with the Ryogoku Kokugikan Sumo Stadium, which integrated a rainwater harvesting system into its infrastructure. This was soon followed by installations in other public facilities, including Sumida City Hall. These systems collect rainwater for non-potable uses such as toilet flushing and vehicle washing.

To encourage uptake in the private sector, the city introduced subsidies and regulations in 1995 for the installation of RHS in new buildings, and since 1988 has promoted community-based "Rojison" facilities, equipped with hand-operated pumps for both daily and emergency use. Complementary measures — such as mandatory green roofs on public buildings and permeable pavements on sidewalks — were introduced to further support flood resilience, enhance urban biodiversity, and help mitigate the urban heat island effect.

Through this integrated approach, Sumida City has emerged as a model of circular and resilient water management, with its strategies replicated in other parts of Tokyo and water-stressed regions around the world.

Circularity & resilience solutions

Decentralised RHS: Sumida City developed technical guidelines to promote the widespread adoption of standardised, ready-made RHS. These include rooftop catchments, conveyance infrastructure, basic filtration (nets, baskets, or sedimentation boxes), underground storage tanks, and plumbing and pumping components.
Community-level "Rojison" systems: Built and maintained in close collaboration with local communities, these systems collect rainwater from rooftops and store it underground (Figure 1). Water can be accessed via hand pumps, and some installations include filtration to make the water safe for drinking during emergencies.
Permeable pavements: Sidewalks have been resurfaced with permeable materials that facilitate groundwater recharge and reduce surface runoff.

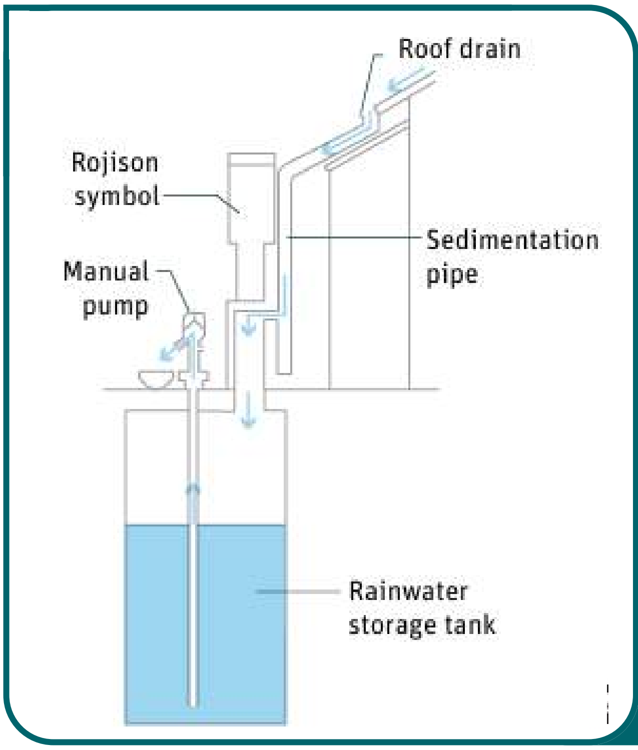


Figure 1. Sectional Diagram of a “Rojison”
Source: World Bank (2019)

Urban planning and policy

1995
Introduction of the Rainwater Utilisation Promotion Subsidy System, providing subsidies for rainwater harvesting systems in private buildings.

1995
Development of installation standards and technical guidelines by Sumida City.

2003
Introduction of a regulatory requirement for new buildings with a surface area larger than 10,000 m² to install rainwater harvesting systems.

2006
Enactment of the *Sumida Basic Environmental Ordinance*, identifying rainwater utilisation as a priority action and determining the involvement of businesses and citisens in it.

2007
Based on the Environmental Ordinance, adoption of the First Sumida Environment Co-creation Plan — Sumida's highest-level environmental policy — which established city-wide goals for collective rainwater utilisation.

2008
Enactment of the Apartment and Condominium Housing Ordinance, providing guidance for private rainwater harvesting systems. Under this ordinance, buildings meeting the following criteria are subject to specific requirements:

	Non-target building: < 1,000 m², <15 units or <5 stories	Target building: ≥ 1,000 m², ≥15 units, ≥5 stories
Site < 500 m²	No specific requirement	✓ Pavement infiltration required
Site ≥ 500 m²	✓ Pavement infiltration required	✓ Pavement infiltration required ✓ Rainwater harvesting required

2009
Sumida City designated as an "Environmental District," establishing rainwater utilisation as a central to its urban environmental strategy.

2011
Implementation of the *Sumida City Basic Plan* for Green, incorporating policies to promote greenery that reflect the city's traditional culture, such as planting along narrow streets and the integration of rainwater-utilised alley chimes and water chimes.

2016
Launch of the Second Sumida Environment Co-creation Plan (2016–2025), outlining comprehensive policies to enhance rainwater storage and utilisation as a means to mitigate urban flooding and improve water resource management.

2022
Interim revision of the *Second Sumida Environment Co-creation Plan*, reaffirming the promotion of rainwater utilisation as a key strategic project for advancing a sustainable urban environment.

Climate and environmental impacts

Mitigation of greenhouse gases: Localised rainwater harvesting systems significantly reduced the carbon footprint associated with water supply by eliminating the need for energy-intensive, long-distance water transport and large-scale infrastructure projects. By harvesting 10,000 m3 of rainfall annually, Sumida can mitigate 2.6 tons of CO_2 emissions every year.

Adaptation and resilience: The implementation of RHS, green roofs, and permeable sidewalks have enhanced the city's capacity to manage stormwater, preventing urban flooding. These systems also secure access to non-potable water during disasters or droughts. Additionally, the green infrastructure helps attenuate the Urban Heat Island effect.

Biodiversity: Research shows that the green roofs in Sumida have enriched local biodiversity, with the occurrence of rare species.

Others environmental benefits:

- Enhanced groundwater recharge through permeable surfaces.
- Reduced surface runoff, lowering pollutant concentrations in local water bodies.

Financing, funding, and O&M

- **Public sector facilities:** The municipal budget supports the installation and maintenance of RHS in public buildings.
- **Private sector facilities:** The municipality provides subsidies and co-financing mechanisms for the installation of RHS in private buildings. These can cover up to JPY 1 million (approximately EUR 6,200) or 50% of the total installation cost. By 2022, a total of JPY 36.8 million in subsidies were disbursed, with the total investment in private facilities reaching at least JPY 72.5 million (EUR 451,000).
- **Community facilities:** The costs and subsidies of the "Rojison" systems — installed, operated, and maintained by neighborhood residents and non-profit organisations — are outlined below:

Tank type	Description	Subsidy amount	Maximum
Underground storage tank	The underground pit is used as a rainwater storage tank for large buildings, condominiums, etc. Stored water is used mainly for washing, toilets, and watering plants.	Subsidy amount 1m^3: ¥40,000 (USD363) times effective storage capacity (m^3)	Up to ¥1 million (US$90,909)
Mid-size storage tank	Tank with storage capacity of 1m^3 or more. Stored eater is used mainly for washing, toilets, and watering plants.	Tanks made of fiber-reinforced play (FRP), stainless steel, or concrete: subsidy amount per cubic meter ¥120,000 (US$1,090) times effective storage capacity (m^3) Tanks made of high-density polyethylene: subsidy amount per cubic meter ¥45,000 (US$409) times effective storage capacity (m^3)	Up to ¥300,000 (US$2,727)
Small storage tank	Tank with storage capacity less than 1m^3. Stored water is used mainly for watering plants	50 percent of rainwater tank, including cost of construction	Up to ¥40,000 (US$363)

- **Cost-benefit analysis:**
  - Most installations recover their costs within 10 years through savings on municipal water bills.
  - Additional economic benefits include reduced costs from flood damage and reduced pressure on public water infrastructure.

Stakeholder engagement and social inclusion

- **Community involvement through "Rojison" systems:** The 20 “Rojison” facilities were established with the active participation of residents, who are also responsible for maintenance. These systems enhance community resilience and provide practical infrastructure.
- **Collaboration with NGOs and businesses:** The non-profit organisation People for Rainwater, established in 1995, liaises between the local government, residents, and the private sector, promoting rainwater use and advising households on the installation of RHS. The Association of Businesses for Rainwater Utilisation, founded in 2001, collaborates with architects and manufacturers to develop affordable, standardised systems.
- **Networking and awareness-raising initiatives:** In 1996, Sumida City co-founded the Liaison Association of Municipalities in Charge of Rainwater Utilisation, a network of over 125 municipalities promoting rainwater harvesting across Japan. The City has also organised events around the topic, including the International Rainwater Conferences in 1994 and 2005. Additionally, it runs multiple awareness-raising initiatives, including educational activities at local schools and the Sumida Rainwater Museum.

Contributors to success

Values: Recognition of water as a key resource to be harvested, with a focus on decentralised, community-based ownership of rainwater harvesting facilities. Educational initiatives raise awareness of the importance of rainwater harvesting.

Connections:

1. **Physical connections:** Locally embedded networks of water catchment, storage, and distribution have created a cohesive infrastructure system that supports rainwater harvesting across Sumida City.
2. **Social connections:** The success of the initiative is driven by knowledge-sharing and community-building, including the following actions:
   a. Empowering local communities through participation in rainwater management and maintenance.
   b. Fostering collaboration across sectors, including government, NGOs, and businesses, to promote sustainable water practices.
   c. Creating platforms for continuous learning about and awareness of the benefits of rainwater harvesting.

Investments: Rainwater harvesting facilities are cost-effective, providing sufficient savings to make them financially feasible. Subsidies help address high initial costs for both public and private sectors.

Replicability

The Sumida City Rainwater Utilisation Initiative, launched in Tokyo in 1982, exemplifies a cost-effective and scalable model for urban water resilience. Over four decades, it has demonstrated how decentralised rainwater harvesting, integrated with green infrastructure and community engagement, can effectively mitigate flood risks and reduce reliance on external water sources. With low maintenance requirements, integration into building regulations, and active participation from both the public and private sectors, the Sumida case offers a replicable solution for cities facing similar challenges.

In Morocco, where urban areas experience limited and irregular rainfall, adopting Sumida's approach could enhance water security and climate resilience. Installing rainwater harvesting systems in public and private buildings, coupled with permeable surfaces and community-managed storage facilities, could optimise the use of scarce rainfall. Such measures align with Morocco's national strategies for sustainable water management, and can be tailored to local contexts, offering a practical and proven framework for addressing water scarcity and urban flooding.

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Chapter 1: Decentralised, place-based and participatory systems

ETHEKWINI METROPOLITAN MUNICIPALITY, SOUTH AFRICA

- Decentralised wastewater treatment and reuse
- Urban ecosystems restoration and biodiversity
- Community co-creation and stewardship

City overview

Population: 4,239,901 million (2022)
Climate: Humid subtropical (Köppen Cfa)
Rainfall: 975 mm/year (moderate)
Water-related risks:

- **Flooding** due to steep coastal catchments and storm surges, with high risk of overwhelmed wastewater facilities and raw sewage discharges into the Umbilo River and other urban waterways.
- **Sewage overflows** during storms and power outages, releasing effluent into rivers, estuaries, and beaches, causing high risk of E. coli contamination.
- **Water shortage** during periods of drought, forcing emergency restrictions.
- **Water-borne diseases**, with residents facing outbreaks of cholera, diarrhoea, typhoid, and hepatitis because of damaged sanitation infrastructure following severe flooding.

Case study overview

Initiative name: Decentralised Wastewater Treatment System (DEWATS) program
Location: Newlands East, Durban, eThekwini Metropolitan Municipality, South Africa
Period: 2014–Present
Initiative type: Decentralised Wastewater Treatment & Reuse
Scale of initiative: Neighborhood/District
Project developers: eThekwini Water & Sanitation, University of KwaZulu-Natal (UKZN), Bremen Overseas Research & Development Association (BORDA)
Project objective: Deploy modular, gravity-driven, and decentralised wastewater treatment plants for 84 households (750 users) in Durban's informal settlements to boost water resilience, protect public health and waterways, and recover water, energy, and nutrients for sustainable urban water management.

Main interventions

- **Installation of the Newlands-Mashu decentralised wastewater treatment systems** (DEWATS) in townships and housing projects in Newlands East, eThekwini, using natural, low-energy processes. These systems include the following:
- **Modular treatment system** capable of treating approximately 41,000 L of domestic wastewater per day using simple, natural processes. In other sites, similar DEWATS can treat up to 1.5 million L per day.
- **Gravity-driven infrastructure** enabling off-grid operation without pumps or external power, ensuring continuity during power cuts ("load-shedding").
- **Biogas capture system** integrated with the primary settling and anaerobic treatment stages to allow for local energy use, reducing the demand for grid electricity or fuel.
- **Effluent reuse** by diverting treated wastewater to on-site drip irrigation systems for food crops such as bananas and taro.
- **Composting of scum and sludge** using drying beds, producing nutrient-rich compost that is reused in local agriculture and landscaping.

Main outcomes

- **Waste water treatment and recycling:** Up to 41,000 L of domestic wastewater is treated daily; the treated wastewater is then reused for non-potable purposes, such as irrigation.
- **Improved water quality, environmental health, and biodiversity in nearby waterways:** Compared with untreated effluent, water discharged from the DEWATS contains 85% fewer organic pollutants and 75% fewer suspended solids, reducing eutrophication and enhancing aquatic biodiversity in adjacent water bodies, such as the Umgeni River.
- **Improved public health:** Reduced raw sewage spills during floods have reduced the incidence of *E-Coli* contamination. Long-term monitoring of the Newlands-Mashu DEWATS demonstration site shows a 98.4% reduction in *E. Coli* between the raw influent and the treated wetland effluent.
- **Food security:** Utilising treated wastewater for irrigation supports agricultural productivity, thereby contributing to food security in the community.
- **Enhanced water resilience:** In other sites (e.g., the International School of Tanganyika in Dar es Salaam, Tanzania), DEWATS enhance water resilience during droughts and crises by enabling the reuse of treated wastewater for non-potable purposes, such as toilet flushing, ensuring a reliable and safe supply of water for essential needs.

Project cost

Approximate cost of a domestic wastewater system for approximately 84 household (750 users):

- **Investment:** Approx. ZAR 5 million (approx. EUR 240,000 in 2025 or, EUR 715,000 in 2010)
- **Operations and maintenance (O&M):** Approx. ZAR 30,000 (approx. EUR 1,400) per year (including two full-time site technicians, personal protective equipment, and scum removal material)

Project

Context

The eThekwini Metropolitan Municipality, located on South Africa's east coast, is the country's third-largest municipality, home to approximately 4.24 million people. Its steep, flood-prone coastal terrain faces growing water risks, including drought and storm damage. During the 2014–2016 drought, restrictor washers were installed on over half a million water connections to manage demand. In 2022, severe flooding damaged roads and wastewater treatment infrastructure, leading to sewage spills into the Umbilo River and extended beach closures due to unsafe E. coli levels. These repeated crises — combined with rapid urbanisation and the expansion of informal settlements — prompted eThekwini Water & Sanitation to explore more resilient, decentralised approaches to wastewater management. One key solution has been the implementation of neighborhood-scale Decentralised Wastewater Treatment Systems (DEWATS), a technology developed by the Bremen Overseas Research & Development Association (BORDA), a German NGO. Since its first pilot project in 1989, DEWATS has become a proven, sustainable sanitation solution, with over 2,700 units installed worldwide treating 57,000 m^3 of wastewater everyday. It has successfully served diverse communities in 16 countries across Asia, Africa, and Latin America.

Project description

Implemented with the support of BORDA as a technical facilitator and process consultant, DEWATS employs modular, decentralised, gravity-driven designs that combine anaerobic reactors, baffled reactors and constructed wetlands. These systems operate without electricity or chemicals, enhancing urban resilience while advancing circular economy principles. In South Africa, the eThekwini's Newlands East community hosts a demonstration and research DEWATS facility. Built in 2010, and operationalised in 2014, the system treats up to 41,000 L of domestic wastewater from 84 households and 750 users per day. The treated effluent is reused for irrigating crops like bananas and taro, supporting both water security and local food production. Building on the success of this initiative, several DEWATS for public toilets and schools, and the proven track record of this technology globally, eThekwini is now planning to scale up the initiative across the city, with the installation of a DEWATS as part of the upgrade of the Banana City informal settlement. The model's potential to deliver resilient, decentralised sanitation solutions offers valuable insights for Moroccan cities.

Circularity and resilience solutions

- **Modular, multi-stage treatment design:** The Newlands-Mashu DEWATS unit includes a two-chamber settling tank, three parallel anaerobic baffled reactors, two anaerobic filters, and a hybrid wetland system (Figure 1). First, vertical flow removes ammonia; thereafter, horizontal flow further polishes the wastewater.
- **Effluent reuse for irrigation:** Treated wastewater is used in the automated drip-irrigation of food crops, reducing demand for freshwater and commercial fertiliser while enhancing food security.
- **Biogas capture:** Methane-rich biogas produced during anaerobic digestion can be harnessed for cooking or heating, creating a local renewable energy source, reducing the demand for grid energy, largely derived from fossil fuels.

- **Flood and drought resilience:** The treatment of wastewater discharge of clean water reduces the public health risk associated with flood events, while also improving drought resilience by providing up to 41,000 L of non-potable water for household use per day.
- **Modular, scalable design:** A DEWATS unit can serve 20–1,000 households, and can be expanded incrementally. This limits its immediate spatial impact, allows capacity to be increased as settlements expand, and supports adaptive urban resilience.

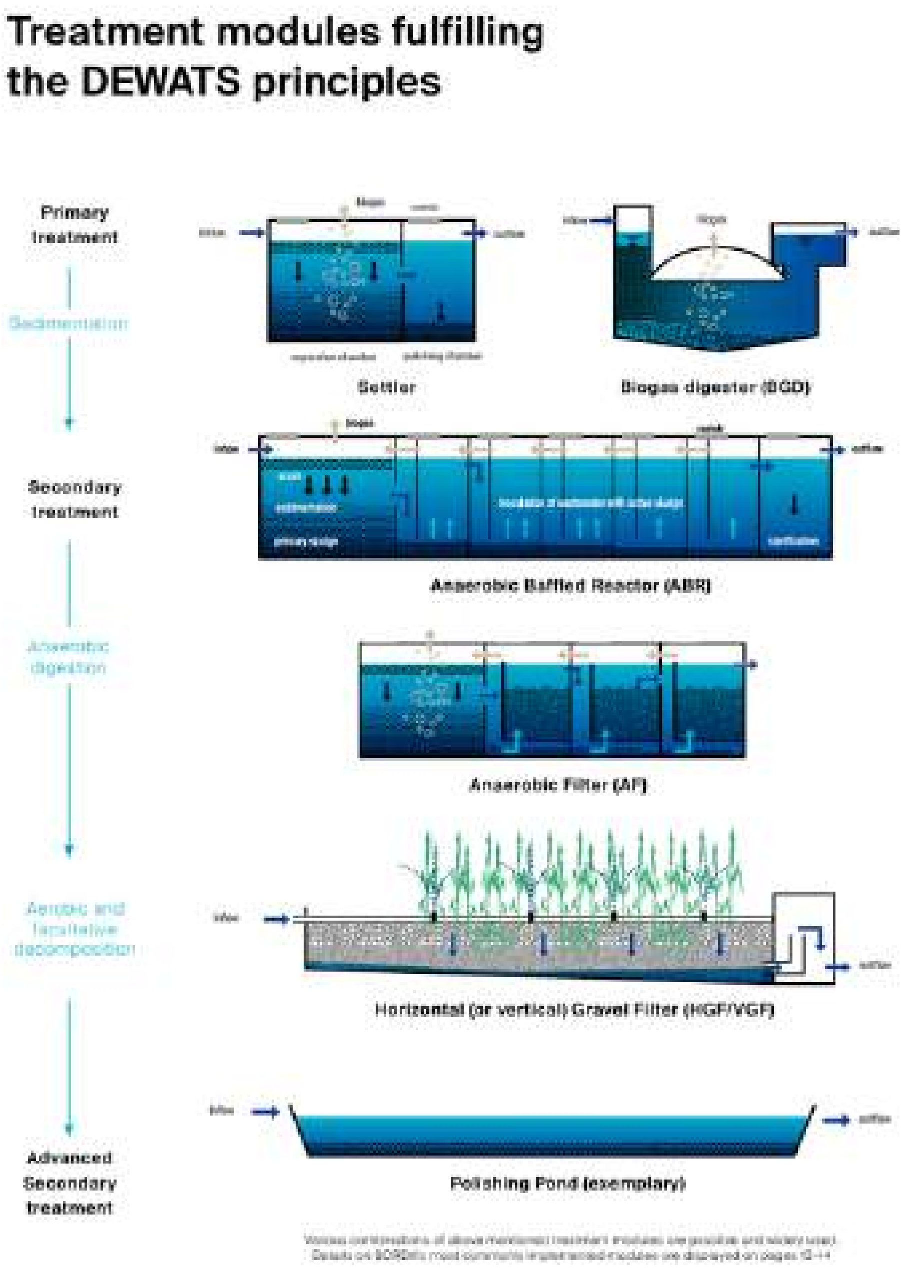
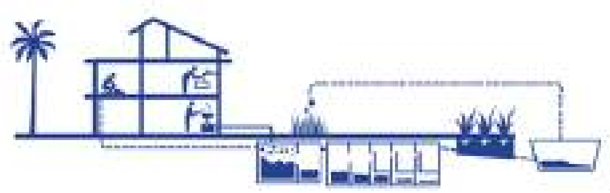


Figure 1: Diagram of DEWAT principles and treatment modules.
Source: BORDA (2017)

Planning and policy timeline

2010
The eThekwini Municipality commissions the evaluation of a demonstration-scale DEWATS in Newlands East with BORDA and the University of KwaZulu-Natal (UKZN) to assess the feasibility of decentralised sanitation solutions.



2014
The Newlands-Mashu DEWATS becomes fully operational.

2016
The *National Sanitation Policy* encourages the use of decentralised sanitation systems in South Africa.

2023
eThekwini's *Integrated Development Plan* highlights the municipality's commitment to exploring circular and decentralised sanitation solutions, such as the DEWATS.

2021 & 2024
Two memorandums of understanding are signed between eThekwini Water & Sanitation and BORDA South Africa, aiming at city-wide upscaling and implementation of DEWATS.

Climate and environmental impacts

Mitigation: DEWATS plants capture methane from wastewater for use in cooking or heating. They also operate without electricity, which reduces the demand for grid electricity and fossil fuels and decreases greenhouse gas (GHG) emissions. Compared to conventional, centralised wastewater treatment plants, DEWATS are associated with significantly lower GHG emissions because of their lower energy consumption and simpler biological treatment processes. However, methane from anaerobic digestion stages remains a critical emission source; therefore, the effective capture and combustion of methane as a biogas is essential to fully realise this technology's mitigation benefits.

Adaptation and resilience: DEWATS operate entirely through gravity, without pumps or external power, ensuring uninterrupted treatment during power cuts, floods, or other disruptions. Its decentralised design treats wastewater locally, reducing pressure on centralised infrastructure and preventing sewage overflows during climate-driven shocks, such as floods.

Biodiversity: The Newlands-Mashu DEWATS removes 95% of organic pollutants and 75% of suspended solids from wastewater, reducing nutrient and sediment loads discharged into adjacent water bodies, such as the Umgeni River), creating healthier ecosystems and increasing species richness among aquatic fauna and flora.

Financing and funding

Cost structure:

- **Investment:** Approx. ZAR 5 million (approx. EUR 240,000 in 2025 or, EUR 715,000 in 2010)

- **Operation and maintenance:** Approx. ZAR 30,000 (EUR 1,430) per year (including two full-time site technicians, personal protective equipment and scum removal material)

Finance sources and instruments:

- **Public sector investment:**
  - eThekwini Water & Sanitation covered the construction and equipment costs of the Newlands-Mashu plant.
  - BORDA, funded by philanthropy and public resources, provided the design for the DEWATS plant.
- **Private sector investment:** In other sites, BORDA has utilised private-public partnerships (PPPs) for the implementation of DEWATS, and collaborates with the private sector by designing operational models, training operators, and supporting technical execution.
- **Civil society:** O&M is undertaken by the local community, with small costs for equipment replacement. benefits include avoided costs from flood damage and reduced pressure on public water infrastructure.

Cost-benefit analysis:

- **Reduced infrastructure costs:** Eliminating the need for sewer networks can lead to significant capital savings. In South Africa, this cost can reach up to ZAR 25 million (EUR 1.25 million) per kilometer.
- **Lower energy consumption:** Decentralised systems reduce reliance on energy-intensive pumping, resulting in significant energy savings. A DEWATS model implemented by O&M Solutions has achieved an approximately 45% reduction in energy costs compared to centralised wastewater treatment systems.
- **Water savings:** Treated effluent can be reused for non-potable purposes such as irrigation, reducing freshwater abstraction and associated supply costs.
- **Energy recovery:** Biogas captured from the anaerobic stages reduces demand for grid electricity, cutting energy expenses.
- **Climate resilience and avoided damage:** Decreased vulnerability to flood-related failures reduces the economic impact of extreme weather events.
- **Cost recovery:** Through the above savings, household DEWATS can recover their initial costs after 3–4 years.

Stakeholder engagement and social inclusion

Community participation and education: In Newlands East, BORDA, UKZN, and eThekwini actively engaged the local community through ongoing communication and training local residents to operate and maintain the system. This empowered the community and fostered ownership over the infrastructure, ensuring long-term sustainability.

Capacity-building and local employment: DEWATS are designed with community-level implementation in mind. Local residents are trained and employed in the construction, operation, and upkeep of the systems, building technical capacity and promoting social inclusion.

Knowledge-sharing: The Newlands-Mashu Research Site, established by BORDA with eThekwini Water & Sanitation and UKZN, serves as a live demonstration and research hub for DEWATS. It supports hands-on training for researchers and practitioners. Knowledge exchange is promoted through workshops, seminars, and international presentations led by BORDA and UKZN, contributing to broader dissemination of DEWATS best practices.

Contributors to success

Values:

1. Recognition of domestic wastewater as a source of water, energy, and nutrients, rather than merely a waste product in need of disposal.
2. Realizing the benefit of human-scale, decentralised systems for building climate resilience.

Connections:

1. Physical connections: DEWATS offer an off-grid, modular solution that integrates wastewater treatment, reuse, and resource recovery.
2. Social connections: The success of the initiative is driven by knowledge-sharing and close community engagement:
   a. Capacity building and collaboration with local residents enables community-led operation and maintenance, fostering a sense of ownership over the DEWATS infrastructure.
   b. Regular communication through workshops and educational materials mainstream values around wastewater reuse and resource recovery.
   c. A global network of researchers and practitioners led by BORDA support the implementation of DEWATS systems through forums, academic publications, and technical exchange.

Investments: Low investment and operational costs, combined with community-led O&M, create a cost-effective model for scaling the system.

Replicability

The DEWATS model has proven to be globally applicable, with over 2,700 systems deployed across diverse geographies and climates — including arid, water-scarce regions. These decentralised, modular, low-energy systems offer reliable wastewater treatment without external power or chemicals, making them suited for informal and underserved urban areas. Another strong example of successful DEWATS implementation as a cost-effective and scalable model for urban water resilience is the SANIMAS project in Indonesia, where the national government rolled out a large-scale, community-based DEWATS program that provided decentralised sanitation services to low-income urban areas. Launched in 2003 as a pilot by BORDA and WSP, a Canadian consulting firm, it saw the installation of over 13,000 units by 2019 (with a further 20,000 planned installations) through collaboration with local governments, communities, and national funding schemes. The program combined modular DEWATS designs with operator training and CBO-led maintenance, establishing a benchmark for inclusive and sustainable sanitation in Southeast Asia.

In Morocco, where many municipalities face challenges related to water scarcity and rapid urbanisation, and are upgrading informal settlements through the *Villes sans bidonvilles* initiative, adapting the DEWATS model could strengthen water security and climate resilience. Cities such as Agadir and Rabat — which are seeing rapid peri-urban growth and are undertaking active informal settlement upgrading and sanitation expansion initiatives — could benefit from modular, decentralised wastewater treatment systems in underserved communities. By embedding these systems in planning and building codes, training community operators, and leveraging blended funding, cities can tailor this proven framework to close water and nutrient loops, protect public health, and enhance local capacity for a sustainable and circular wastewater management.

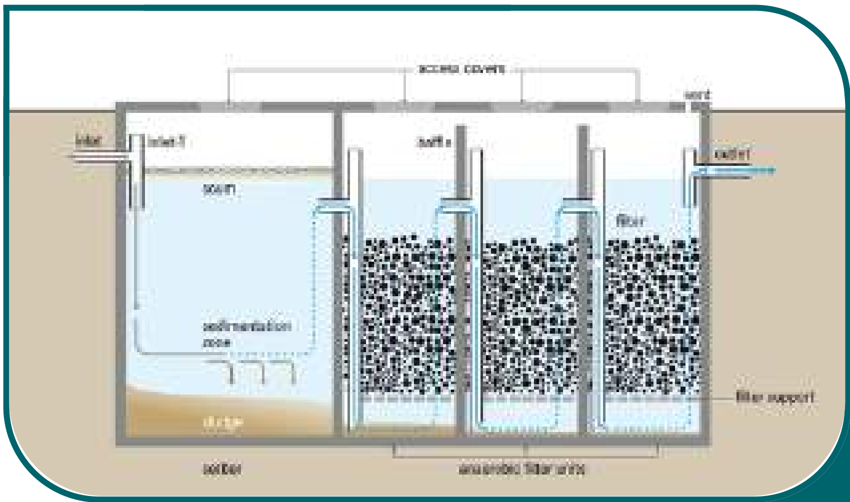


Figure 2: Decentralised wastewater treatment system. Source: BORDA (2017).

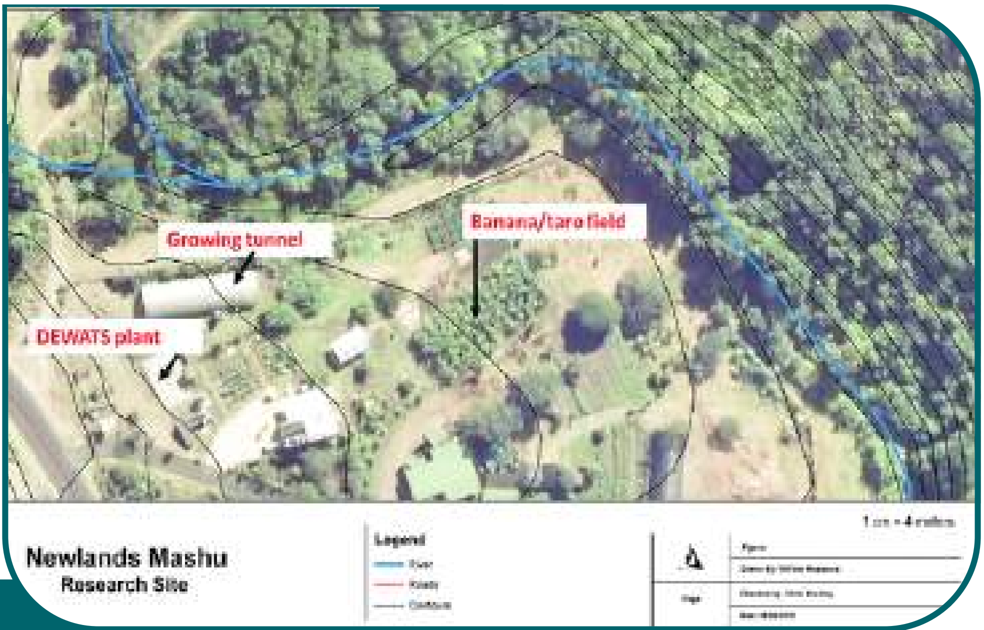


Figure 3: A map of the Newlands-Mashu pilot site, showing the DEWATS, experimental field, and adjacent Umgeni River.
Source: Musazura et al. (2018).

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Chapter 1: Decentralised, place-based and participatory systems

IZTAPALAPA, MEXICO CITY, MEXICO

- Rainwater harvesting and reuse
- Stormwater management and flood mitigation
- Groundwater recharge
- Decentralised wastewater treatment and reuse
- Green-blue infrastructure / nature based solutions
- Community co-creation and stewardship

City overview

Population:
- Mexico City Metro: 22,752,400 (2025)
- Iztapalapa: 1,835,000 (2020)

Climate: Subtropical highland climate, characterised by warm summers and mild winters (Köppen Cwb)
Rainfall: 860 mm/year (moderate)
Water-related risks:
- **Frequent flooding** arising from excess rainfall channeled from the Sierra de Santa Catarina mountain range into low-lying urban areas.
- **Chronic water shortages** due to overcrowding, lack of urban planning, and high rates of non-revenue water loss.

Case study overview

Initiative name: La Quebradora Hydraulic Park (Parque Hídrico La Quebradora or Utopia Atzintli)
Location: Iztapalapa, Mexico City, Mexico
Period: 2017–2021 (design and construction)
Initiative type:
- Groundwater recharge
- Stormwater management & flood mitigation
- Decentralised wastewater treatment & reuse
- Green-Blue infrastructure / nature-based solutions

Initiative scale: Site-specific
Project developers: Iztapalapa Municipality, Mexico City Public Space Authority, National Autonomous University of Mexico (UNAM)
Project objective: Address persistent flooding and water shortages in Iztapalapa using innovative infrastructure that combines ecological restoration with the creation of multifunctional public space.

Main interventions

- **Public park and amenities** established on previously unused urban land, creating a dynamic community hub featuring a library, swimming pool, bookstore, workshops, recreational areas, and a community center.
- **Stormwater channels** to redirect rainwater from nearby areas into the park, where it is filtered using screens and absorbed through **permeable basins**, promoting groundwater recharge.
- **Rainwater harvesting** through terracing, wetland systems and rain cisterns.
- **Wastewater treatment and reuse** for irrigation and flushing of toilets.

- **Sustainable landscaping,** replacing water-intensive lawns with hardscapes that do not require irrigation and native or endemic tree species that need little water.

Main outcomes

- **Flood mitigation and groundwater recharge:** The initiative increased water catchment capacity by 35%, leading to an infiltration rate of approximately 68,000 m^3/year, recharging groundwater to total capacity of 36,000 m3. Improved filtration and sedimentation enhance water quality, support aquifer recharge, and ensure long-term water security.
- **Stormwater management and rainwater harvesting:** The 3.8 ha basin captures mountain runoff, recharges the underlying aquifer and harvests rainwater at a rate of ~86.4 m^3/day for park and toilet use.
- **Accessible public space and urban facilities:** The project benefits 28,000 local residents, doubling the accessible public space in Iztapalapa from 1.13 to 2.97 m2 per person and attracting around 7,000 visitors weekly (UNAM Foundation, 2021).
- **Increased vegetation coverage:** The initiative tripled the number of trees in the area through the planting of endemic species.

Project cost

MXN 490 million (EUR 22.3 million)

- **First phase (cleaning of the area, groundwork for basins):** MXN 134 million (EUR 6.1 million)
- **Second phase (buildings, facilities, the urban design concept, and the construction of a wastewater treatment plant):** MXN 205 million (EUR 9.9 million).

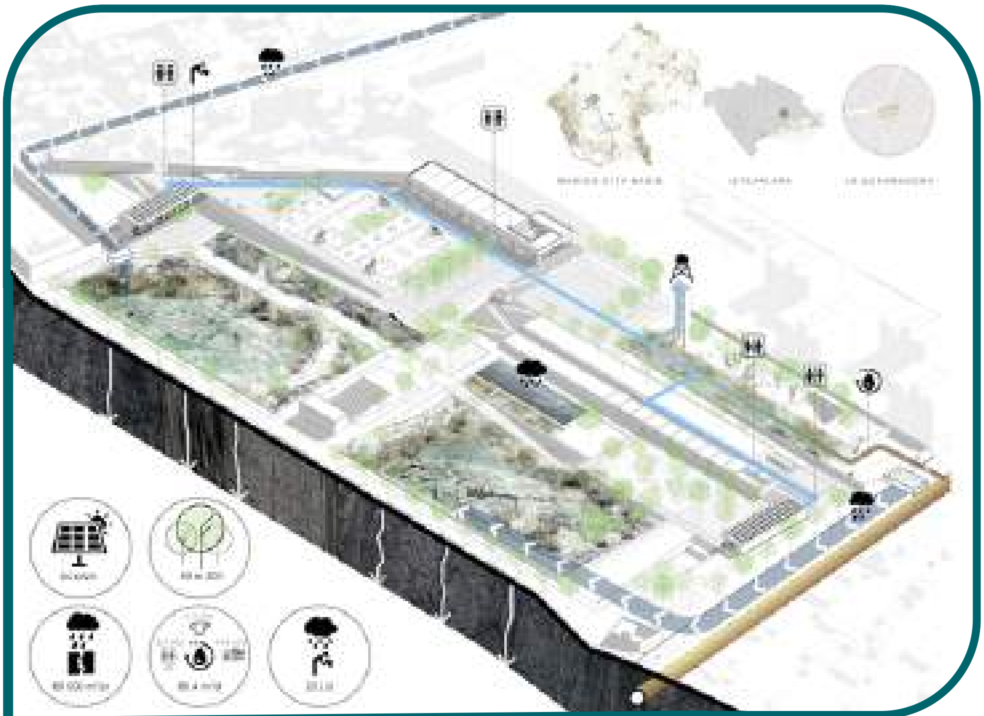


Diagram of the design and main interventions of the La Quebradora Hydraulic Park.
Source: Arquine (2018)

Project

Context

Mexico City faces a distinct water crisis marked by extreme water scarcity and periodic flooding due to a legacy of poor water management and excessive urban development in the Valley of Mexico Basin. The area of Iztapalapa is especially affected by frequent flooding from intense rains originating in the nearby Sierra de Santa Catarina mountain range, while also suffering from severe water scarcity. Although water is brought in from other basins, infrastructure failures result in high distribution losses. Consequently, many residents must rely on water delivered by trucks — a costly and unreliable stop-gap measure. High population density, informal settlements, and insufficient urban planning further compound the challenges. In response, researchers at the National Autonomous University of Mexico (UNAM) designed the La Quebradora Hydraulic Park as a demonstration of "hydro-urban acupuncture" — an approach to water management that integrates different types of decentralised, multifunctional water infrastructure to address urban water challenges.

Project description

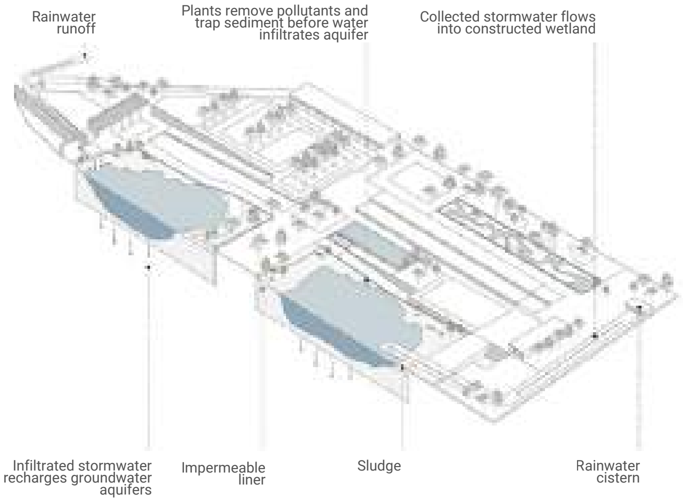
La Quebradora is a 3.8 ha hydrological park in Iztapalapa, Mexico City, designed to manage stormwater through decentralised infrastructure while providing green public space and community facilities. Located on the hillside of the Sierra de Santa Catarina, the park captures and filters rainwater, recharges the underlying aquifer, supplies non-potable water for toilets and irrigation, and offers recreational, ecological, and educational amenities for residents in one of the city's most water-stressed areas.

The project was initiated in 2013 by a team from UNAM. After initial delays, it gained momentum in 2016 with support from a new local administration. A detailed design was completed in 2017, and construction began in early 2018. Despite interruptions due to insufficient funding and political changes, international recognition — including the LafargeHolcim Global Gold Prise — helped revive the project. In 2021, the park was inaugurated under the official name of Utopía Atzintli, as part of a broader municipal program to transform public spaces in Iztapalapa. Community participation was central throughout, shaping a resilient, multifunctional space that redefines how urban infrastructure can respond to environmental and social challenges.

Circularity technologies and solutions

- **Stormwater channels and permeable basins:** Covering 3.8 ha, the park collects rainwater from nearby areas using stormwater channels. The water is filtered through screens and passes into permeable basins, infiltrating the underlying soil and recharging groundwater. This system helps prevent flooding on key streets like Ermita Iztapalapa Avenue — a major thoroughfare for commuters and public transport — while also replenishing groundwater reserves still used by local residents, improving the area's long-term water supply.
- **Wastewater treatment plant:** In addition to collecting rainwater, the park also treats wastewater drawn from a nearby drainage channel using a system that combines an anaerobic biological treatment plant with a subsurface wetland. The treated water is used to meet the park's daily needs and to supply pavilion installations, where residents can bring containers to collect water. This has proven particularly helpful for those who do not have reliable access to water at home.

- **Use of local materials:** Construction utilised local volcanic stone, minimizing transportation impacts and supporting local economies.



Schematic of the main circular water technologies employed in the La Quebradora Hydraulic Park. Source: Conrad & Voraakhom (2024).

Planning and policy timeline

1970–1990
Iztapalapa experiences rapid urbanisation, leading to water management infrastructure deficits and a lack of public spaces. Rising demand from residents to transform the La Quebradora site into a public park.

2002
Next Mexico City, a vision for Mexico City's waterscape, is presented at the Venice Architecture Biennale, proposing the reintegration of water into the urban fabric by restoring historical lakebeds and ecosystems.

2013
Iztapalapa Municipality commissions UNAM to research the district's hydrological conditions. Due to the limited authority of local governments in Mexico over water management, the team proposes a hydro-urban acupuncture strategy, based on the theory that rapid, targeted interventions can significantly improve water management in the area without disrupting general urban planning. La Quebradora was proposed as the first project in this strategy.

2015
Iztapalapa Municipality hires UNAM to design the La Quebradora Hydraulic Park.

2017
Construction of La Quebradora begins.

2018
Post-election changes in the local administration halt the project. La Quebradora wins awards from the Holcim Foundation for Sustainable Construction and the Development Bank of Latin America.

2019
Following pressure from the community and international recognition, the new administration permits construction to resume and integrates the project into Iztapalapa Municipality's Utopías policy to reconvert abandoned spaces into functional, inclusive and sustainable public areas.

2021
The La Quebradora Hydraulic Park is inaugurated.

Climate and environmental impacts

- **Mitigation:** Localised groundwater recharge and rainwater harvesting systems offer a sustainable alternative to costly, carbon-intensive, and large-scale gray infrastructure designed for long-distance water transport from Cutzamala. Replacing water trucks with community water points further reduces greenhouse gas emissions and contributes to improved air quality.

- **Adaptation and resilience:**
  - **Flood risk mitigation:** Permeable basins, constructed wetlands, and cisterns help manage stormwater locally, reducing flood risk.
  - **Addressing water scarcity:** Rainwater harvesting and treatment systems supply non-potable water for irrigation and sanitation. Permeable basins support aquifer recharge, enabling sustainable groundwater use by local communities. These supplementary water sources help compensate for scarce water supply from external sources.

- **Biodiversity:** Pathways offer multiple routes through the 3.8 ha site, allowing fauna to move through the area. Additionally, the park comprises a range of endemic or locally adapted vegetation, which have tripled the number of trees in the area.

Financing and funding

- **Total cost:** Approx. MXN 490 million (EUR 22.3 million)
- **Finance sources and instruments:**
  - **Public sector investment:**
    - Federal government (Federal Contributions Fund for Social Infrastructure): MXN 250 million (EUR 11.4 million)
    - Iztapalapa Municipality: MXN 50 million (EUR 2,28 million)
  - **Other sources (undisclosed):** MXN 190 million (EUR 8,664)*
- **Blended sources:** All operations and maintenance (O&M) are conducted and funded through a public-private partnership between the Iztapalapa Municipality, private sector, local community, and academia. The municipality manages the park, under the guidance of a council formed by all partners. The sources of operational funds are outlined in Table 1.

**Note:* *Public sources do not specify the origin of the remaining public funds.*

Table 1. Percentage contributions of different partners and revenue sources to the O&M of the La Quebradora Hydraulic Park.

	Iztapalapa Municipality	Local revenues (library, public toilets, advertising, cell phone tower)	Civil society and private donors
Short-term operation (<5 years)	50%	25%	25%
Long-term operation (>5 years)	25%	50%	25%

- **Cost-benefit analysis:**
  - **Reduced flood damage:** By mitigating urban flooding, the project helps reduce damage to homes, infrastructure, and public services, lowering costs for emergency response, repairs, and insurance.
  - **Reduced water supply costs:** The supply of non-potable water through rainwater harvesting and treatment systems, coupled with aquifer recharge, reduces the demand of the park and local communities on external sources of water, reducing direct municipal water supply costs and indirect costs for the maintenance of centralised water infrastructure.
  - **Indirect financial benefits:** While specific data on avoided costs are not available, the project's long-term benefits, including improved public space, higher property values, and better quality of life, suggest it is a cost-effective alternative to traditional, mono-functional gray infrastructure.

Stakeholder engagement and social inclusion

- **Community engagement:** Actors involved in the project include local and regional government as well as civil society and academia. One of La Quebradora's main strengths is its strong connection with the local community. Between 2013 and 2017, the design team conducted numerous workshops to tailor the park's features to the specific needs of Iztapalapa's residents, which resulted in the inclusion of new facilities such as the swimming pools. Community pressure was also instrumental in restarting the project after it was halted by a newly elected administration in 2018. Today, residents remain actively involved through the park's administrative council. This participatory approach has fostered a strong sense of ownership and long-term support.

- **Social impact:** The project is located in a municipality where most residents face difficult living conditions, with limited access to recreational and sports facilities, and ongoing issues of both water shortages and flooding. In response, the park was designed to provide more space for social and recreational use, reduce flood risks, and help address water scarcity. Additionally, it features a dedicated center supporting women affected by violence, highlighting its broader commitment to social equity.

Source: Giuroiu, A. (2025). architecturelab.

Contributors to success

Values: The project aligns with the principle of hydro-urban acupuncture, suggesting that targeted, hyper-local, and small-scale interventions can systemically improve water management without the need for amended urban plans or large-scale redevelopment. It also integrates elements of the sponge city concept, redefining public space to serve not only functional and aesthetic purposes, but also as hydrological and educational infrastructure — managing water flows while reintroducing water's presence into the urban landscape.

Connections:

1. **Physical connections:** The park channels urban runoff from the Sierra de Santa Catarina into infiltration basins, creating a connected network for recharging the local aquifers and providing water to public standpipes.
2. **Social connections:** The project has been supported by strong connections with the local community, fostering ties between civil society, academia, and government through a participatory-design model.

Investments: La Quebradora demonstrates a model to finance circular and resilient water infrastructure through multi-level investing, sourcing funds from national and local governments as well as private donors. By combining the stormwater management infrastructure with high-quality public space, La Quebradora offers a compelling investment case for public authorities and other stakeholders, making it possible to channel funds into water management systems while gaining strong community support and visibility. By complementing public investment with additional funding from private donors, the project's financing model is an important contributor to its success.

Replicability

La Quebradora serves as a replicable model for sustainable urban water management across Mexico and beyond. The project has inspired adaptations in municipalities such as Ecatepec (Mexico), Tijuana (Mexico), and Nogales (Arizona, USA) through projects that integrate flood control, water reuse, and public space.

The approach also holds strong replicable potential in Morocco. Its hydro-urban acupuncture strategy could be particularly relevant for Moroccan cities aiming to enhance water circularity and resilience in densely built environments — contexts where a large-scale approach may require costly urban redevelopment. La Quebradora's model of integrating groundwater recharge and stormwater management with public space also offers a valuable reference for suburban areas in Morocco seeking to implement localised, low-cost, multi-functional infrastructure. In Tétouan, for example, where informal settlements around the Martil River basin are vulnerable to stormwater runoff from nearby hills, similar terraced public spaces, infiltration zones, and decentralised retention basins could help manage water flows while improving the urban environment.

Source: Giuroiu (2025). architecturelab.

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Chapter 1: Decentralised, place-based and participatory systems

IBN TOFAIL UNIVERSITY, KÉNITRA, MOROCCO

Decentralised wastewater treatment and reuse

Community co-creation and stewardship

City overview

Population:
- Kenitra: 507,736 (2024)
- ITU campus: Over 50,000 water users

Climate: Hot-summer Mediterranean climate, with mild winters and dry summers (Köppen Csa)
Rainfall: 571 mm/year (moderate)
Water-related risks:
- **Growing water demand:** The expansion of agriculture, industry (notably the automotive and agrifood sectors), and university activities have increased pressure on local water resources.
- **Water pollution:** The university's proximity to the Sebou River and underlying aquifer exposes the area to risks of surface and groundwater contamination resulting from untreated or insufficiently treated wastewater and industrial effluents.
- **Resource stress:** Increasing water abstraction carries the risk of overexploiting the Sebou River basin and local aquifers, threatening long-term water availability.
- **Climate variability:** The potential impacts of climate change may exacerbate water scarcity and pollution challenges, undermining urban resilience and sustainable development.

Case study overview

Project name: Ibn Tofail University Wastewater Treatment Plant and Living Lab (WWTP-Living Lab)
Location: Ibn Tofail University, Kénitra, Morocco
Period: 2019 – Ongoing
Project type: Wastewater treatment plant and living lab
Project scale: Site-specific
Main project leads: Ibn Tofail University (ITU) and Separation Processes Laboratory
Project objective: Enhance the university's capacity to treat wastewater, reuse treated water for irrigation, reduce surface and groundwater pollution, provide a hands-on research and training platform for students, and raise visitor awareness of sustainable water management.

Main interventions

- **Installation of a treatment plant** based on a membrane bioreactor (MBR) to efficiently treat wastewater from campus laboratories and buildings.
- **Reuse of treated wastewater** for irrigation 25% of the campus' green spaces in compliance with quality standards. The reuse system comprises the following components:
  - A subsurface irrigation network installed across the irrigated areas.
  - A 40 m³ storage tank that collects treated effluent.
  - A chlorine-based disinfection unit that treats water stored in the reservoir before its redistribution for irrigation.
- **Demonstration and education site** created for students and professionals. The site promotes hands-on learning, capacity building, and knowledge transfer in sustainable water treatment technologies, including membrane bioreactors (MBR), monitoring tools, and reuse practices.

Main outcomes

- **Improved wastewater treatment capacity:** The MBR plant treats approximately 500 m³ of wastewater daily from campus laboratories and buildings, corresponding to a total of approximately 170,000 m³ of treated water in 2024.
- **Reduced potable water demand:** Currently, the 170,000 m3 of treated water produced by the MBR plant is used to irrigate 25% of the university's total green area (approx. 5 ha). The reuse of this treated water has reduced the university's potable water consumption by 70%.
- **Improved water quality:** Wastewater treatment and reuse in compliance with water quality standards have significantly reduced surface and groundwater pollution.
- **Education and capacity building:** The site serves as a demonstration and training center for students and professionals. Each year, the site hosts over 10 technical workshops and site visits, engaging more than 90 participants, including students from engineering and environmental sciences programs, university professors, municipal staff, and professionals from the water sector.
- **Sustainability and autonomy:** The university has achieved autonomy in locally treating its wastewater, improving operational sustainability and reducing reliance on municipal services.
- **Energy efficiency:** The MBR system operates with an energy consumption of approximately 0.2 kWh/m³ of water treated, resulting in an annual consumption of 33,230.87 kWh in 2024. This is considerably more efficient compared to conventional activated sludge systems, typically consuming 0.3–0.5 kWh/m³.

Project cost

MAD 8 million (approx. EUR 760,000)

Project

Context

Located at the mouth of the Sebou River, adjacent to the RAMSAR-listed Marjat Al Fouwarate agrifood, the city of Kenitra faces several critical water challenges. Its mixed economy — which combines intensive agriculture, expanding industrial activity, and a growing university campus — places increasing pressure on local water resources. Key concerns include the pollution of both surface and groundwater, primarily due to untreated urban discharges, agricultural runoff rich in nutrients and pesticides, and industrial effluents. In addition, the city's location in a historically marshy zone makes it particularly vulnerable to seasonal flooding, a problem that has been exacerbated by urban expansion and inadequate stormwater infrastructure. The early 2000s saw multiple flood events, highlighting the city's exposure and the urgent need for resilient water and land-use planning.

Given these pressures, the development of decentralised, sustainable water management systems has become a local priority. Within this context, the Ibn Tofail University (UIT) implemented the Wastewater Treatment Plant and Living Lab project (WWTP-Living Lab) as both a technical solution and an educational platform (Figure 1). It prioritises water circularity, pollution control, and flood mitigation by integrating wastewater treatment and reuse, local capacity building, and nature-based infrastructure — positioning the campus as a model for urban water resilience in the region.

Project description

Launched in 2019, the ITU WWTP was established to promote sustainable water management on the university campus. The initiative began with the installation of a membrane bioreactor (MBR) system designed to treat wastewater generated by laboratories and campus buildings. Treated water is then reused for irrigating 25% of the university's green spaces, reducing reliance on conventional freshwater resources and contributing to local water resilience.

Beyond its technical function, the WWTP has evolved to include a living laboratory, supporting applied research, student training, and awareness-raising on environmental protection and circular water practices. The facility hosts regular workshops, site visits, and collaborative projects involving both students and professionals.

Complementary initiatives have been implemented to enhance system efficiency and educational impact, including a subsurface irrigation network, a civil-engineered storage reservoir with a capacity of 40 m^3, and a chlorination unit for post-treatment disinfection. These measures ensure compliance with quality standards while offering a practical demonstration of integrated water reuse systems.

Through this comprehensive and inclusive approach, the ITU WWTP-Living Lab has become a model for nature-positive, decentralised water reuse on academic campuses with potential for replication in other urban and semi-urban institutions facing water stress.

Figure 1. Exterior view of the ITU WWTP-Living Lab.
Source: Ibn Tofail University

Circularity and resilience solutions

MBR process: In order to treat wastewater to a high quality suitable for reuse, this compact, decentralised process combines biological treatment and membrane filtration. The ultrafiltration membrane comprises two types of membrane: a hollow fiber and flat membrane. The treatment process includes a lifting station, pre-treatment unit, biological and membrane treatment, and sludge and odour treatment (Figure 2). The performance of the WWTP during the years 2023–2024 is detailed in Tables 1 and 2.

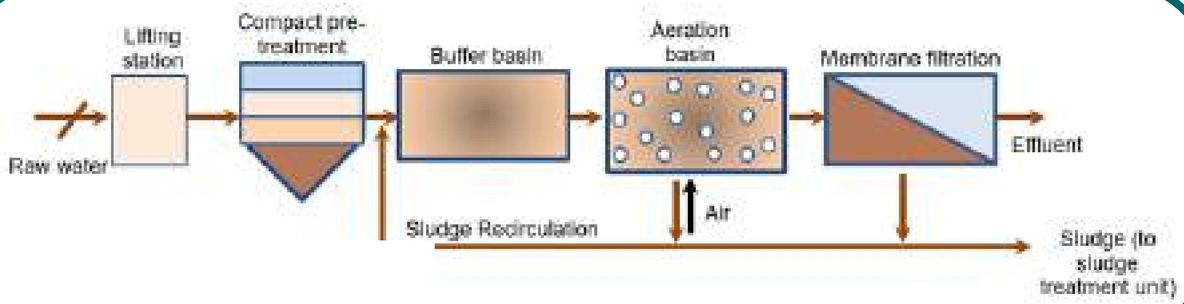

Figure 2.1: Flow diagram of the treatment process employed in the ITU WWTP.
Source: Ibn Tofail University

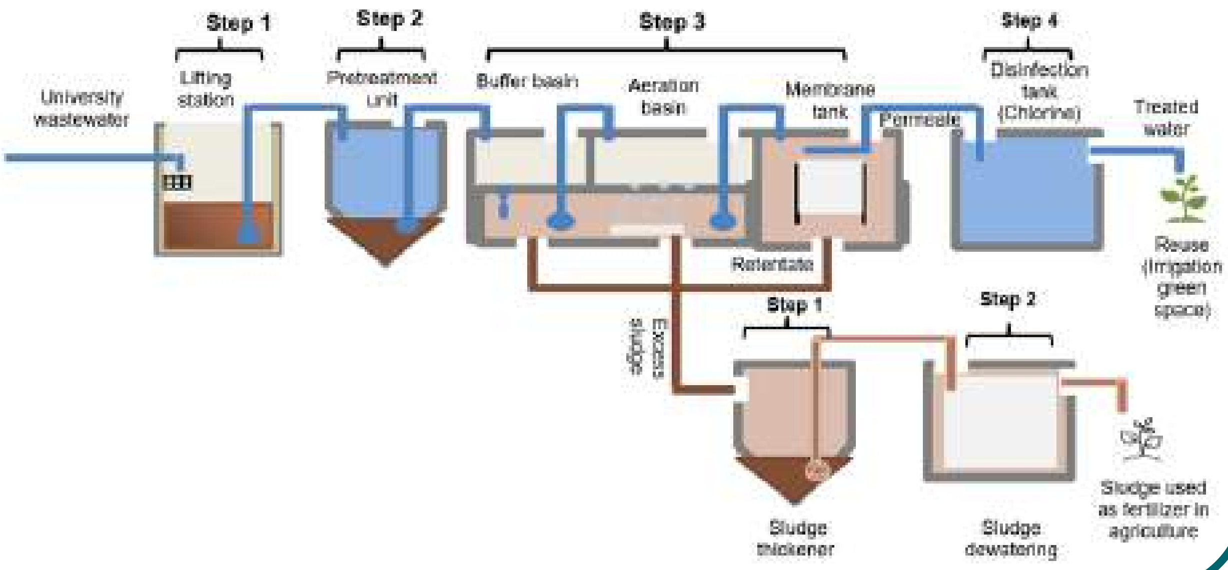

Figure 2.2: Flow diagram of the treatment process employed in the ITU WWTP.
Source: Ibn Tofail University

Table 1. Physico-chemical parameters of the performance of the ITU WWTP in 2023 and 2024.

Variable	2023			2024		
	Quality: raw water	Quality: treated water	Total water treated	Quality: raw water	Quality: treated water	Total water treated
COD[a] (mg/L)	500	27	150,000 m3/year)	540	31	170,000 m3/year
BOD5[b] (mg/L)	360	20		380	23	
SS[c] (mg/L)	490	2.5		500	3.9	
Nitrogen (mg/L)	26	6		22	8	
Phosphorus (mg/L)	7	2		9	1	

[a] Chemical oxygen demand
[b] 5-day biochemical oxygen demand
[c] Suspended solids

Table 2. Bacteriological parameters of the performance of the ITU WWTP in 2023 and 2024.

Variable	Treated water (2022/2023)
	Maximum concentration
Fecal coliforms	< 1000 FC/100 mL
Nematode eggs	None

Integrated reuse system: To reuse the treated water, the facility includes a subsurface irrigation network and 40 m³ storage reservoir with chlorine-based disinfection (Figure 3). Additionally, ongoing studies are exploring options for sludge valorisation for soil conditioning in campus green spaces.

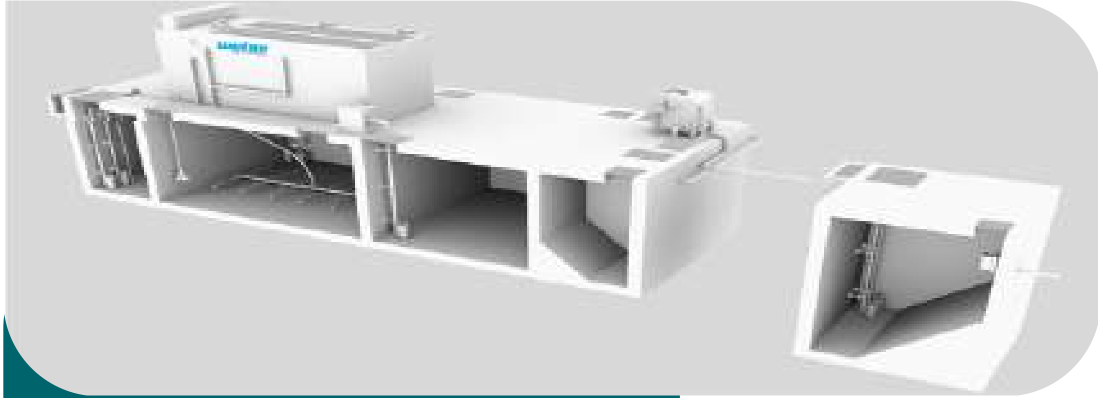

Figure 3: 3D model of the ITU WWTP, showcasing the semi-buried basins and membrane tank

Wastewater reuse: Treated water is subsequently reused to irrigate approximately 25% of the campus's green spaces using the underground irrigation technology, reducing reliance on potable water (Figure 4).

Compact and integrated design: The system is space-efficient and designed to minimise nuisances such as odors or noise, making it suitable for urban campus settings (Figure 5).

Figure 4. Green space on the ITU campus irrigated using treated wastewater.
Source: Ibn Tofail University

Planning and policy timeline

2010
Morocco adopts the Water Sector Development Strategy and National Water Plan, aligning with other strategies with a strong focus on water.

2015
The Rabat-Sale-Kenitra Regional Development Plan is introduced, with an emphasis on protecting the environment, public health, reducing water pollution, and the valorisation of unconventional water resources for irrigation.

2016
Law No. 36-15 establishes the principle of integrated water resources management in Morocco.

2019
In response to the preceding policy frameworks, ITU initiates the construction of a WWTP with a capacity of 400 m³/day.

2023
ITU, in partnership with German company INNARI, installs the trademarked Mipotube subsurface irrigation system in green areas around the campus treatment plant.

2024
ITU is recognised for its strong commitment to national priorities in water, health, energy, agro-industry, and digital innovation.

Ongoing
Following the initial success of the treatment facility, ITU has established a platform dedicated to experimentation, innovation, and training in the water sector. It focuses on developing solutions to enhance water management, while reducing losses and optimizing usage.

Figure 5. Interior of the ITU WWTP, highlighting its compact design. Source: Ibn Tofail University

Figure 6. Diagram of the underground irrigation system (left) and detailed image of INNARI Mipotubes.
Source: Ibn Tofail Campus Communications Staff in collaboration with Prof. Sakina Belhamidi and the INNARI team.

Climate and environmental impacts

Mitigation: The project contributes to reducing indirect greenhouse gas emissions by lowering the university's reliance on centrally treated potable water and its associated energy footprint. To support this, ITU has launched a solar energy initiative that currently supplies approximately 30% of the WWTP's electricity demand through photovoltaic panels, with a target of reaching 60% coverage by 2030. This shift toward renewable energy is expected to significantly reduce the plant's carbon footprint and enhance energy resilience.

Adaptation and resilience:

- Wastewater reuse significantly reduces pressure on drinking water supplies, contributing to climate change adaptation through freshwater conservation, and offsetting a substantial volume of conventional water use, especially during dry seasons.
- The WWTP's design allows for off-grid operation, ensuring continuous treatment and reuse even during external energy supply disruptions, which is vital in the context of climate-related risks.
- Sludge from the treatment process is currently being stabilised and stored, and feasibility studies are underway to valorise it for soil improvement in campus landscaping, further closing the resource loop.

Environment and biodiversity: The treated wastewater supports a subsurface irrigation system for 25% of the campus green areas, helping to maintain healthy vegetation, reduce surface runoff, and enhance microclimatic cooling. This contributes to local biodiversity preservation, especially near the Marjat Al Fouwarate RAMSAR site, by reducing nutrient-rich runoff and supporting a greener, more climate-resilient campus environment.

Financing and funding

Cost structure: The project benefits from low operations and maintenance costs, thanks to energy efficiency measures and the integration of renewable energy, with long-term sustainability ensured by the university's in-house technical teams.

Financing sources and instruments:

- State grant from the Rabat-Sale-Kenitra regional government: MAD 4.6 million (approx. EUR 418,500)
- Self-funding by ITU: MAD 3.4 million (approx. EUR 309,000)

Cost-benefit analysis:

- The project has already reduced the university's reliance on external, potable water sources by approximately 170,000 m^3/year, representing an estimated cost saving of over MAD 680,000 (approx. EUR 62,000) annually (based on average water tariffs).
- The project results in uncalculated indirect savings for the university and surrounding area through its preservation of freshwater supplies and contribution to climate resilience.
- The project provides strong justification for public investment through its demonstrated local, regional, and academic impacts.
- The WWTP Living Lab generates indirect economic value through the following:
    - Training services and technical visits, some of which are monetised for external professionals.
    - Collaborative research and innovation projects, including patentable technologies in water treatment and reuse.
    - Future prospects for resource recovery (e.g., treated sludge for soil amendment) which may yield additional environmental and financial returns.

Stakeholder engagement and social inclusion

Stakeholder engagement: The project benefits from diversified stakeholders involved in financing, design and operation, as summarised in Table 3.

Table 3: Key stakeholders involved in the ITU WWTP-Learning Lab.

Stakeholder	Role
Ibn Tofail University	Owner and operator of the WWTP
Rabat-Sale-Kenitra Region	Project co-financer
Separation Processes Laboratory	Technical and scientific support
Public bodies: National Office of Electricity and Drinking Water, Ministry of Environment, Ministry of Higher Education	Potential regulators or technical partners
Users and students	Further capacity building and knowledge sharing

Social inclusion: The project employs three main forms of social inclusion:

- **Active participation of the academic community:** The project actively involves ITU students, researchers, and staff by providing hands-on training, and research opportunities as well as experimentation platforms related to wastewater treatment and sustainable water management.
- **Inclusion of vulnerable groups:** Women, youth, and the broader local community are engaged indirectly through targeted awareness campaigns and open-access training programs, fostering wider community involvement and environmental literacy.
- **Promoting a just transition:** The initiative ensures equitable access to environmental knowledge and resources, reducing disparities in access to quality water for irrigation. It encourages local innovation and educational efforts to support inclusive and sustainable development.

Contributors to success

Values:
Education has been central to the WWTP-Learning Lab, integrating circularity and sustainability with awareness-raising on wastewater treatment. The project values small decentralised treatment systems as a key approach for resilient, local water management. University involvement has been crucial in building capacity. It upholds the human right to water and sanitation, values healthy ecosystems, and promotes water's multiple benefits.

Connections:

1. **Physical connections:** The WWTP-Living Lab is physically integrated into the university's water and landscape management systems. Treated wastewater is conveyed through a dedicated underground distribution network connected to a subsurface irrigation system. The plant is also connected to monitoring infrastructure for water quality control and energy consumption, supporting research and educational activities.
2. **Social connections:** Strong links between the university, regional government, private sector, researchers, and the wider community were key to the project's success. These networks facilitate knowledge sharing and collaborative problem-solving. Engagement with diverse stakeholders encourages cross-sectoral collaboration.

Investments: Collaboration between regional government, university, and local stakeholders enabled the investment. Financial feasibility is boosted by cost savings from treated wastewater reuse for irrigation, making the project feasible and cost-effective even at small scale.

Replicability

The Kenitra Wastewater Treatment Plant project demonstrates a practical and scalable approach to enhancing urban water resilience by integrating wastewater reuse and education at the university level. Its focus on small, decentralised, modular wastewater treatment systems allows flexible adaptation to diverse urban contexts. By combining treated wastewater reuse for irrigation with education and capacity building among the university and local stakeholders, it offers a robust model for water-scarce cities and districts. Collaboration between regional government, academia, and communities strengthens ownership and supports long-term operation and maintenance.

In other Moroccan cities and university campuses facing water scarcity and climate variability, adopting Kenitra's modular, decentralised approach can improve water security and promote circular water management. Small- to medium-scale wastewater reuse systems, combined with targeted awareness and training programs, can be tailored to local conditions. This model aligns with national priorities for sustainable water use and climate adaptation, providing a replicable framework for cities seeking cost-effective, resilient solutions.

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Chapter 2: Urban integration and regenerative planning

SHENZHEN, GUANGDONG, CHINA

- Stormwater management and flood mitigation
- Groundwater recharge
- Green-blue infrastructure / nature based solutions
- Urban ecosystems restoration and biodiversity
- Public-private and multilevel governance models

City overview

Population: 13,545,000 (2025)
Climate: Humid subtropical climate influenced by monsoons (Kööppen Cwa)
Rainfall: 1,933 mm/year (very high)
Water-related risks:

- **Urban flooding:** Based on the 2016 national and municipal flood risk assessment, Shenzhen had 446 identified flooding locations. The largest affected area spanned 500,000 m2, with floods reaching depths of up to 2.5 m and lasting as long as four hours.
- **Water pollution:** Until the early 2000s, Shenzhen Bay and the Pearl River Delta experienced severe water pollution because of weak environmental regulations, inadequate sewage treatment, and poor source control.
- **Water insecurity:** Despite high annual rainfall, Shenzhen faces serious water shortages, with only 154.54 m3 of water available per person annually (7.7% of the national average), placing it among China's 10 most water-stressed cities.

Case study overview

Initiative name: Shenzhen Sponge City Program
Location: Shenzhen, Guangdong, China
Period:

- Chinese Sponge City Program: 2013–Present (Ongoing)
- Shenzhen Sponge City Program:
  - 2016–2020 (planning and pilot in Fenghuangcheng, Guangming)
  - 2019–Present (ongoing city-wide action plan)

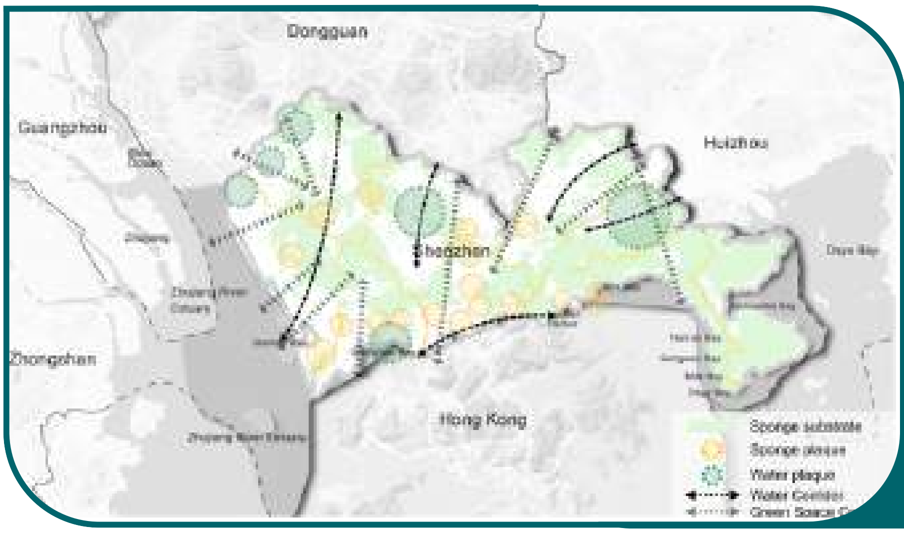
Initiative type:

- Groundwater recharge
- Stormwater management & flood mitigation

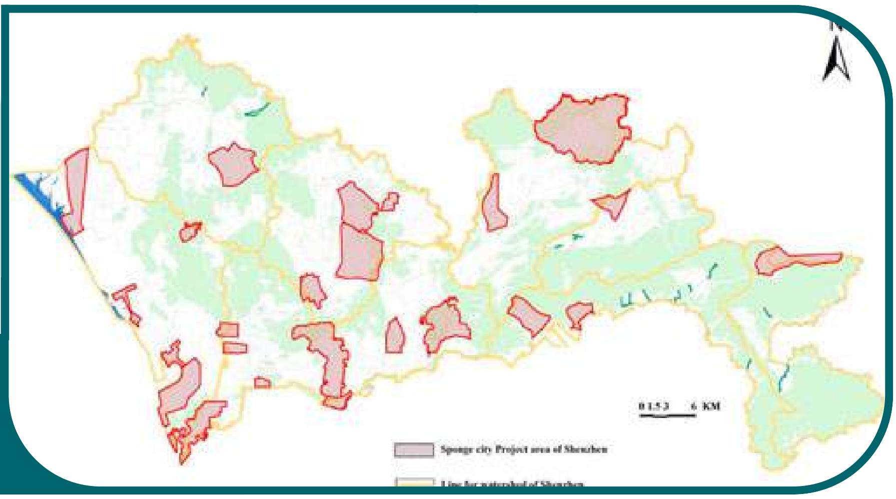
Initiative scale: City-wide
Project leads: Ministry of Housing and Urban-Rural Development, Shenzhen Water Authority, Shenzhen Sponge City Construction Office, District–Level Water Affair Bureaus, District-Level Urban-Rural Development Bureaus
Project objective: The Shenzhen SCP is an integrated urban water management effort designed to improve the city's flood resilience, enhance water quality, and expand water resources by utilizing nature-based solutions.

Main interventions

- **Sponge city planning** based on groundwater level analysis and surface absorption capacity, enabling the development of interconnected green-blue corridors to achieve multi-point water distribution. By 2030, the project will comprise 27 key sponge city construction zones, with over 80% of Shenzhen's built-up area expected to meet sponge city requirements.
- **Green roofs and walls** to harvest and store rainwater (emulating the Green Cloud demonstration project in Gangxia), with excess water being directed to water storage tanks, where water may be treated and reused.
- **Permeable pavements and surfaces** to allow water to infiltrate soil.
- **Nature-based solutions** including low-elevation greenbelts, rain gardens, artificial wetlands, and grass trenches, as in the Xiangmi Park.
- **Stormwater treatment plants,** using a three-stage process to treat stormwater, which is then released into artificial rainwater wetlands, directed into natural water bodies, or reused within buildings for non-potable purposes.



The spatial structure of the Shenzhen SCP.
Source: Jiang & Shan (2021).



Sponge city project areas in relation to Shenzhen watersheds.
Source: Wang et al. (2022).

Aerial view of Biodiverse Xiangmi Park.
Source: mlaplus.com

Main outcomes

- **Sponge city coverage:** Permeable sponge city infrastructure covers 235 km2, or 24%, of Shenzhen's surface area (as of 2020).
- **Reduced vulnerability to flooding:** Sponge city infrastructure captures up to 72% of stormwater in some districts, significantly reducing surface runoff.
- **Improved water quality:** Pollution levels in eight rivers in Shenzhen have significantly decreased, with water quality now meeting national standards, indicative of conditions that can support aquatic life.
- **Increased vegetation coverage:** The project has established a dense network of green infrastructure stretching over 2,300 km, including green corridors, forests, and parks.
- **Reduced urban heat island effect:** Sponge city infrastructure has reduced temperatures in the urban core, with areas such as Fenghuangcheng seeing a drop of 1.9°C in its annual maximum temperature between 2016 and 2018.
- **Enhanced urban livability:** As a result of newly created green spaces, improved landscaping, and cleaner rivers, residents have increased access to natural and recreational areas.

Project

Context

Over the past four decades, Shenzhen has transformed from a fishing village into a major economic hub for technology, financial services, and logistics in southern China. However, this rapid urbanisation — leading to changes in land use, rising population density, and shifts in the local climate — has significantly increased surface runoff, urban flooding, and flood risks. Additionally, the city struggles with water shortages because of its heavy reliance on external water sources and the continually rising demand for water. In response, the Shenzhen government designated the city as part of the second group of national pilot cities for sponge city development in April 2016. The initiative aims to build an international model sponge city, address water-related challenges in a systematic way, and position Shenzhen as a national leader in sustainable water management.

Project description

The Sponge City Program (SCP) is a comprehensive urban water management strategy aimed at reducing surface runoff, water pollution, and flood risks, while using non-conventional water resources to address water shortages. While it aligns with concepts like low-impact development (LID), sustainable urban drainage systems, and water-sensitive urban design, the SCP takes a more holistic and large-scale planning approach. Shenzhen began exploring LID practices in 2004 in the Guangming New Area (now Guangming District), focusing on managing stormwater during heavy rains through features that promote water infiltration, retention, and storage. These early LID projects laid the groundwork for scaling up to the city-wide SCP. Unlike isolated LID interventions, the SCP represents a city-level master plan aimed at advancing sustainable urban development and resilience. It integrates gray, green, and blue infrastructure in a coordinated way to improve the health of ecological systems and provide social benefits. Key components of Shenzhen's SCP include the following:

i. Comprehensive pre-assessments of natural resources, hydrology, and climate to guide spatial planning.
ii. A unified water management strategy.
iii. Tailored designs that respond to local environmental and ecological conditions.

Project cost

Approx. CNY 34.5–48.3 billion (EUR 4.2–5.9 billion)

Circularity technologies and solutions

- **Bioretention catchments and greenways for stormwater management:** Across the different sites, a combination of nature-based solutions is applied to capture, filter, and direct rainwater through bioretention zones and green corridors (Figure 1). These include features like rain gardens, grass swales, and ponds, using vegetation and layered materials of varying permeability, such as plant matter, tree bark, clay, and limestone. These systems work together to slow runoff, enhance infiltration, and retain water underground. An integrated network of subsurface pipes conveys the collected water to storage ponds or designated drainage points, supporting both flood mitigation and groundwater recharge.

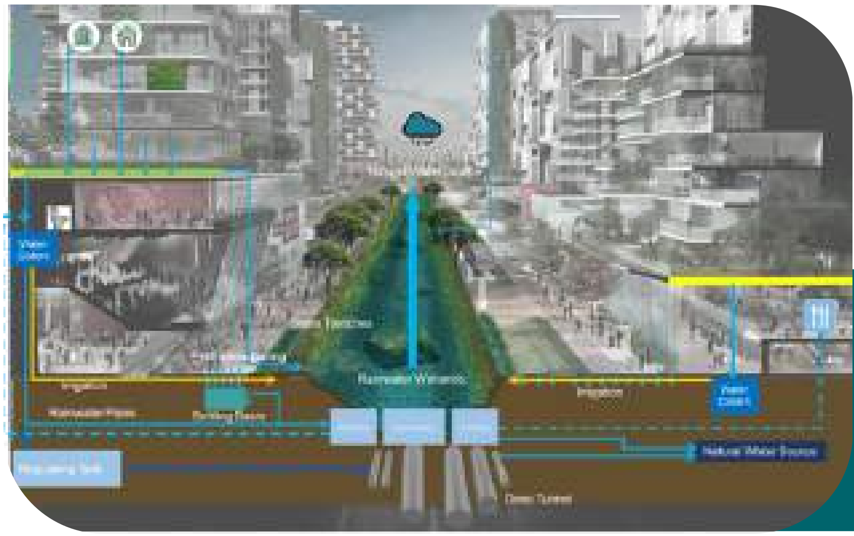


Figure 1. Sectional view illustrating key components of sponge city infrastructure. Source: [Shenzhen Sponge City Construction Office (2017)].

- **Stormwater treatment plants:** In sites like Xiangmi Park, green-blue infrastructure is integrated with a three-stage stormwater treatment system. Treated water is then released into wetlands, redirected to natural bodies, or reused in buildings for non-potable needs.

- **Permeable pavements and surfaces to enhance infiltration:** Permeable pavements allow rainwater to seep into the ground, reducing runoff and flooding. Used on sidewalks, bike paths, and roads, these surfaces are built with layers of gravel and stone that mimic natural soil, slowing water flow and filtering pollutants. They help prevent waterlogging in low-lying areas and support groundwater recharge. For instance, the fully “sponged” No. 38 Road retains up to 60% of annual rainfall, reduces rainwater-borne pollutants by over 50%, and cuts water consumption by 15%.

- **Green roofs and walls:** As implemented in the Green Cloud demonstration project in Gangxia, these features harvest and store rainwater, with excess water being directed to water storage tanks, where it may be treated and reused.

Table 1: Implementing the Sponge City at the District Level in Shenzhen: The case of Fenghuangcheng

Since April 2016, the Fenghuangcheng area in Guangming District, Shenzhen, has served as a pioneering sponge city pilot. This project has established a model for sponge city construction that is now being replicated across China.	
Pilot start: April 2016	**Area:** 24.6 km^2 (including six urban villages and 64 old industrial zones)
Key developers: Guangming District Water Authority, Urban-Rural Development Bureau. **Coordination & oversight:** Shenzhen Municipal Planning & Natural Resources Bureau; Ecological Environment Bureau **Community:** 18 projects involving local residents, schools, and businesses	Key actions: • Creation of ecological control zones (3.8 km2), greenways (47 km), and a coastal ecological space (40 ha). • Construction of rainwater and sewage diversion pipelines. • Upgrade of wastewater treatment facilities and sewage network through a public-private partnership (PPP).
Impact: • Reduced waterlogging and pollution. • Improved urban resilience and ecological health. • Reduced urban heat island effect.	

Planning and policy timeline

2004
Shenzhen begins implementing LID practices in Guangming District, laying the groundwork for future sponge city initiatives.

December 2013
President Xi Jinping officially endorses the sponge city concept.

October 2014
The Ministry of Housing and Urban-Rural Development issues the *Technical Guidelines for Sponge City Construction* and launches the national SCP to improve urban water management and resilience.

2015

- The State Council releases the *Guiding Opinions on the Construction of Sponge Cities (Guobanfa [2015] No. 75)*, setting a goal for cities to manage 70% of rainwater through absorption, retention, and reuse.
- The *Shenzhen Water Quality Enhancement Initiative* (2015–2020) provides a comprehensive plan focusing on four principles: water resource management, environmental water recovery, water safety assurance, and enhancement of visible water bodies.

2015 - 2016
Cities are selected for the first batch of pilot cities of the national SCP, with 16 announced in 2015 and 14 cities in 2016.

April 2016
Shenzhen is designated as part of the second batch of pilot cities of the national SCP. The city develops a three-tiered planning framework comprising city-wide, district, and key area levels, covering 27 key areas totaling approximately 312.7 km².

2018
Shenzhen implements specific construction requirements, with regulations mandating that new, rebuilt, and expanded projects meet specific permeable surface ratios and incorporate sponge facilities like sunken green spaces and rain gardens.

December 2018
Interim Measures for the Construction and Management of Shenzhen Sponge City are issued, covering aspects from planning and construction to operations and maintenance (O&M), to standardise sponge city practices.

January 2019
Shenzhen promulgates the *Shenzhen Sponge City Construction Special Planning and Implementation Plan (Optimisation)*, aiming to minimise the ecological impact of urban development through measures spanning seepage, retention, storage, purification, usage, and discharge, integrating advanced technologies such as cloud computing and big data.

Climate and environmental impacts

- **Mitigation:** The Shenzhen SCP has created approximately 2,300 km of greenways and green areas — such as in Fenghuangcheng, Xiangmi Park, and the Qianhai Water City — which contribute to carbon capture. For example, the Mangrove Seashore Ecological Park (Figure 2), captures approximately 934 tons of carbon annually.
- **Adaptation and resilience:** The Shenzhen SCP has greatly improved urban water management and boosted the city's resilience by minimizing flood impacts, improving water quality, and enhancing ecosystem services. Areas that comply with sponge city standards have reduced their stormwater runoff by 75% and are able to capture and utilise up to 70% of local rainfall, substantially increasing Shenzhen's ability to adapt to urban flooding. The SCP has also helped reduce the urban heat island effect. Fenghuangcheng, which has been a pioneering area of the city in adopting sponge city principles and green infrastructure, has experienced a decrease of 1.9°C in its maximum annual temperature
- **Biodiversity:** Ecologically, the restoration of riparian vegetation helps to gradually enhance urban biodiversity. This supports ecological recovery by helping restore ecosystem integrity. At the Mangrove Seashore Ecological Park, for instance, the number of bird species increased from 53 to 80 in 2023 compared to 2016, and the total bird population rose by 34.5% (Figure 2).

Figure 2. Bird species occurring at the Mangrove Seashore Ecological Park. Source: Lu et al. (2022).

Financing and funding

- **Cost:** Implementation of sponge city infrastructure according to standard per km2: CNY 150–200 million (EUR 18.3–24.4 million)
- **Financing sources and instruments:**
  - **National government:** The National SCP distributed CNY 1.2–1.8 billion (EUR 145–218 million) over three years to local governments to retrofit existing urban spaces.
  - **Local government:** The Shenzhen government covered the remaining investment costs, estimated at CNY 33–46 billion (EUR 4.0–5.6 billion).
  - **Private sector:** Private sector involvement in sponge city initiatives, primarily through PPPs and subsidies, remains at an early stage. However, when involved, the private sector is expected to finance up to 50% of total investments. In the Guangming District, for example, the Plant Network Integration project — comprising the construction of a water purification plant with a treatment capacity of 300,000 m^3/day and a 982 km sewage pipeline network — is being implemented as a PPP. A private company is contributing 51% of the total investment cost of CNY 1.6 billion (EUR 188.9 million), with the government covering the remaining share.

- **Cost-benefit analysis:**
    - **The economic benefits of sponge city projects include the following:**
        - Reduced economic losses caused by flood damage to industry and municipal infrastructure.
        - Reduced costs of water supply during periods of water scarcity.
        - Reduced threats to agriculture and public health resulting from water pollution.
        - Job creation through the construction and subsequent O&M of sponge city infrastructure.
        - Increased tourism revenue from newly created leisure spaces.
        - Enhanced social benefits through greater access to recreational opportunities in parks and green spaces.
    - In Changde's sponge city initiative, for example, a study demonstrates that the economic benefits over a 10-year period significantly outweighed the costs. The project generated over CNY 538.4 million (EUR 64.2 million) in returns from an investment of CNY 382 million (EUR 45.6 million), reflecting a 1.4 cost-benefit ratio. Other studies indicate a payback period of 6–12 years, depending on other urban conditions.

Stakeholder engagement and social inclusion

- **Cross-cutting governance:** Cross-departmental task forces have been established at both the municipal and district levels. At the municipal level, the Shenzhen Sponge City Construction Office is responsible for overarching planning and coordination, while corresponding offices operate at the district level. Since the Shenzhen SCP is closely linked with the restoration of aquatic environments, the Water Affairs Bureau at both the municipal and local level also plays a vital role.
- **Community engagement:** Sponge city initiatives work closely with local communities to define the scope of interventions and around subsequent O&M. For instance, the Futian Mangrove Ecological Park, managed by the Mangrove Conservation Foundation, implemented community outreach programs, including nature education centers and birdwatching activities, fostering public awareness and participation in environmental conservation.

Contributors to success

Values: By framing the city as a sponge, the Shenzhen SCP engenders circular and resilient water management principles in the practices of local government and civil society:

- **Water absorption and storage:** Use of permeable surfaces and features like lakes and retention ponds to capture and store rainwater at its source.
- **Flow regulation and purification:** Slowing and filtering water through meandering channels and wetlands to improve water quality and reduce runoff.
- **Ecological integration:** Protecting natural waterfronts as buffers and sinks, and limiting dense development to strengthen water resilience and ecosystems.

Connections:

1. **Physical connections:** The Shenzhen SCP is guided by a comprehensive and integrated plan that connects various groundwater and catchment systems through greenways and blue infrastructure.
2. **Social connections:** At the national level, pilot cities are encouraged to engage in networking events and share lessons learned. At the municipal and district levels, cross-departmental task force teams have been established to coordinate implementation across agencies. A dedicated municipal Sponge City Construction Office leads overall planning and coordination, while district-level offices are responsible for managing and executing local projects. Research institutions and NGOs, such as The Nature Conservancy, have also taken part in the sponge city policy network and support implementation. Lastly, sponge city initiatives like that in Shenzhen collaborate with local communities to determine the work to be done and ensure sustainable O&M.

Investments: The financing model for the Sponge City Program in Shenzhen relies on multilevel funding, drawing from national government grants, local government budgets, and private sector contributions through PPPs. Despite the high initial investment costs, the program demonstrates strong economic justification, particularly through the avoidance of flood-related economic losses. This risk-reduction benefit, combined with co-benefits like improved urban livability and water security, strengthens the investment case for sponge city infrastructure.

Replicability

The sponge city model, as applied in Shenzhen, shows strong replicability potential in cities across the world facing increasing flood and water stress risks, including those in Morocco. Its emphasis on decentralised, nature-based infrastructure — such as permeable pavements, retention basins, and green corridors — offers cost-effective, multifunctional solutions suited to dense urban areas. Many sponge-like solutions are adaptable at different scales, from buildings and communities to districts and entire cities, tailored to local conditions like precipitation, temperature, and soil. In cities like Tétouan or Tangier, where flash flooding and water scarcity intersect, sponge techniques could help manage runoff, enhance groundwater recharge, and improve public space, positioning them as models for urban resilience in similar semi-arid, rapidly urbanizing contexts.

The project's multilevel financing approach and coordinated planning structures can also inspire Moroccan initiatives. While some of Shenzhen's interventions required high levels of investment, the modular and decentralised nature of many sponge techniques — especially those applied to private buildings or smaller urban areas — offers a pathway for Moroccan cities with more limited financial capacity to gradually implement and scale sponge-inspired solutions.

Aerial view of Dadingling Forest Park ca. 2021.
Source: Thornett (2023).

Shenzhen Bay Park, exhibiting greenways for flood retention and bikeways with a permeable surface.
Source: Thornett (2023).

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Chapter 2: Urban integration and regenerative planning

GOOGONG, NEW SOUTH WALES (NSW), AUSTRALIA

- Rainwater harvesting and reuse
- Stormwater management and flood mitigation
- Groundwater recharge
- Centralised water recycling and reuse
- Green-blue infrastructure / nature based solutions
- Public-private and multilevel governance models

City overview

Population:
- 2025: 10,500
- Mid-2030s (projected): 18,000

Climate: Oceanic climate with warm summers and cool winters (Köppen Cfb)
Rainfall: 590 mm/year (moderate) (with high inter-annual variability and multi-year droughts
Water-related risks:
- Chronic water scarcity, with prolonged droughts and water shortages, as seen during the Millennium Drought (2001–2009) and the 2019 drought.
- Dependence on limited surface water from the Queanbeyan River and Googong Dam, which are already strained due to development in the Canberra region.
- Stormwater flooding and erosion due to rapid urbanisation of former rural land, increasing runoff and causing flash flooding and downstream erosion.
- Fast-paced regional growth, heightening the urgency to implement resilient infrastructure and safeguard vital water resources from pollution and overuse.

Case study overview

Project name: Googong Integrated Water Cycle (IWC)
Location: Googong, New South Wales (NSW), Australia
Period:
- 2002–2011: Planning
- 2012–Present: Ongoing township development
- 2013–2020: Implementation of the IWC System

Project type: Decentralised Wastewater Treatment & Reuse; Rainwater Harvesting & Reuse; Stormwater Management & Flood Mitigation
Project scale: Neighborhood/District
Main project lead: Peet Limited (previously Canberra Investment Corporation) and Mirvac (joint township developers); Icon Water (local utility); Queanbeyan-Palerang Regional Council (IWC operator)
Project objective: Establish one of Australia's first large-scale, water-sensitive communities, employing on-site wastewater recycling and rainwater harvesting to reduce potable water consumption, secure a sustainable water supply for the new 18,000-resident town of Googong, and protect the Googong Dam.

Main interventions

- **Township development:** Through a comprehensive master-planning process, Googong was developed as a new town in the peri-urban area on the outskirts of Canberra, with the end goal of accommodating 18,000 residents.
- **Local water recycling infrastructure:** A Googong Water Recycling Plant (WRP) treats wastewater from the newly built township to a high standard suitable for non-potable reuse. With a capacity of 3 million L per day (MLD) and supported by an 8.5 million L recycled water reservoir, it supplies water for irrigating public spaces, residential gardens, toilet flushing, and other non-potable applications.
- **Dual reticulation network:** This entails the installation of a 29 km recycled water distribution system in parallel with the potable water pipeline. Identifiable by its purple pipes and fittings, the network supplies treated water to all properties in Googong, allowing all buildings to reduce their freshwater use.
- **Household rainwater harvesting:** Rainwater tanks installed at each residence captures roof runoff for on-site reuse. Collected rainwater is used in washing machines and for garden irrigation. During normal conditions, rainwater and recycled water meet most non-potable household water needs.
- **Water-sensitive urban design:** Streetscapes incorporate permeable surfaces and bio-retention swales, while the township features retention ponds and constructed wetlands that treat and slow stormwater runoff.
- **Phased implementation:** The Googong IWC is being implemented in four stages aligned with the township's growth. Stage 1, completed in 2015, included the construction of the WRP along with associated pipework and storage reservoirs, with the capacity to treat 1 MLD and serving approximately 4,700 residents. In 2020, after testing and commissioning, the treated water started being recycled and supplied back to the residences. The latest expansion was completed in 2023 and increased the plant's capacity to 3 million litres per day (MLD).

Main outcomes

- **Potable water savings:** The project has led to an estimated 60% reduction in potable water use. Once fully populated, the township's 18,000 residents will use no more potable water than 6,500 people in a typical Australian town, easing pressure on regional water supplies and infrastructure, including the Googong Dam.
- **High wastewater reuse:** In total, 62% of wastewater is recycled on-site and reused for non-potable purposes, reducing discharge volumes and providing a reliable secondary water source. Treated effluent meets the NSW Health and NSW Environment Protection Authority standards for non-potable reuse, with water quality consistently monitored for pathogens, nutrients, and turbidity.
- **Effective stormwater management:** Water-sensitive design reduces peak stormwater flows and improves the quality of runoff entering local creeks, while enhancing groundwater recharge and mitigating erosion during heavy rainfall.
- **Enhanced drought resilience:** The integrated system meets all non-potable water needs with recycled or harvested water under normal conditions. During the 2019–2020 drought, while neighboring towns imposed restrictions, Googong maintained green spaces and essential services, demonstrating the reliability of its internal water cycle.
- **Economic and infrastructure benefits:** Googong is widely recognised as a leading example of water-sensitive community development. It has won multiple awards, including 5-Green Star accreditation from the Green Building Council, and is one of the fastest-selling developments

in Australia, with over 10,500 residents.

Project cost

- IWC: AUD 133 million (EUR 74.2 million)
- Township development: AUD 2.2 billion (EUR 1.2 billion)

Project

Context

In the early 2000s, planning authorities identified Googong — a 780 ha former sheep pasture 16 km south-east of Canberra — as a key site to meet growing regional housing demand (Figure 1). However, water provisioning for this new town posed a major challenge. At the time, the region was experiencing the severe Millennium Drought (2001–2009), and adding thousands of new water consumers to the already strained Queanbeyan River/Googong Dam system was untenable. Moreover, environmental regulations required that the new development not compromise Googong Dam, a protected drinking water reservoir.

In response, the joint township developers, Peet Limited and Mirvac, working closely with state planners and the local council, proposed an integrated water cycle (IWC) model. By drastically reducing external water needs and recycling water internally, the IWC would enable the township to grow to 6,000 dwellings, housing 18,000 residents with minimal impact on regional water supply.

Project description

Launched alongside the first stage of township construction in 2015, the Googong IWC is a comprehensive, closed-loop water management solution. Integrated into the Googong master plan (Figure 2), the IWC is designed to serve the entire community. Wastewater from all properties is piped to the on-site Googong Water Recycling Plant (WRP), where it is treated to high standards in line with Australia's National Water Quality Management Strategy. Over 60% of the treated effluent is recycled, stored in dedicated reservoirs (Figure 3), and distributed via a separate reticulation network for non-potable uses, running in parallel to that for potable water (Figure 4). Rainwater harvesting complements this system: each property is equipped with tanks that collect roof runoff, plumbed to non-potable fixtures such as laundry systems, further reducing demand. Together, these measures have lowered potable water use by approximately 60%.

Delivered in incremental stages, the IWC also incorporates water-sensitive urban design for stormwater management. Permeable surfaces, swales, infiltration zones, and detention basins are embedded throughout Googong to reduce runoff, improve water quality, and support groundwater recharge.

Googong's water cycle is largely self-contained: the only major input is a small volume of freshwater top-up, while excess recycled water and treated effluent are released only under controlled conditions during periods of low demand. The IWC has become a cornerstone of Googong's development strategy, pioneering decentralised water recycling at scale and setting a national precedent in post-drought Australia.

Figure 1. The town of Googong and its surrounding geographical context.

Figure 2. Googong masterplan.

Figure 3. Recycled water storage tanks.
Source: Australian Water Association (2023).

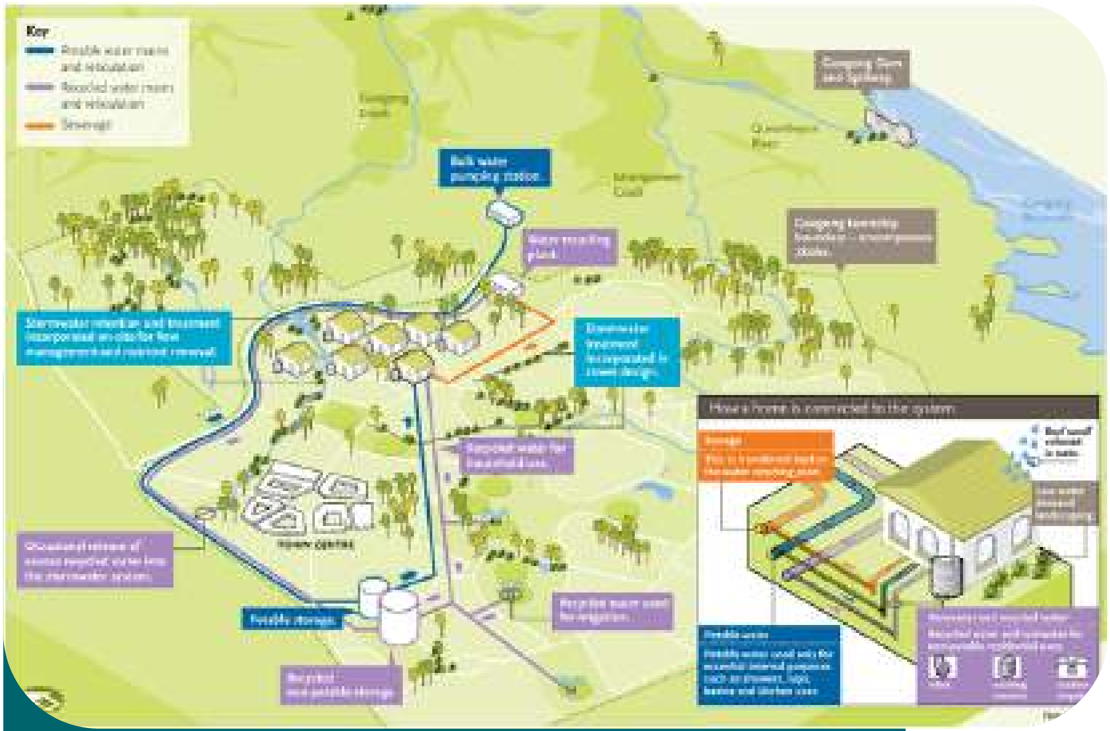

Figure 4. Simplified illustration of the Googong's dual reticulation network.
Source: CIC Australia (n.d.).

Circularity and resilience solutions

Advanced wastewater recycling: The Googong WRP uses modern treatment technology to produce high-quality recycled water for non-potable use and controlled environmental discharge. The treatment process includes the following steps (Figure 5):

- Inlet works for preliminary treatment
- Membrane bioreactor (MBR) for wastewater treatment
- Tertiary phosphorus removal
- UV light disinfection
- Chlorine disinfection

Biosolids reuse: The WRP includes sludge processing facilities, producing biosolids that are reused off-site for agriculture or soil improvement.

Figure 5. Googong wastewater treatment process.
Source: Queanbeyan-Palerang Regional Council (n.d.).

- **Dual distribution system:** A parallel network of purple-coded pipes delivers recycled water to all toilets, garden taps, and irrigation systems in Googong (Figure 6). Separate from the potable waster reticulation system, it includes dedicated reservoirs and pumping stations. All components are clearly labelled to prevent cross-connection and ensure public awareness that the water is non-drinkable (Figure 7).

Supply	
Supply	**Connection point**
Drinking water supply	Shower/bath cold water
	Kitchen, bathroom and laundry tub cold water
	Hot water system
	Dedicated outdoor drinking water taps (uses include pool filling and pool top up)
	Air-conditioner/cooling system
	Refrigerator (if required for icemaker)
	Dishwasher
	Backup hot and cold taps for washing washine
Rainwater supply	Washing machine primary cold water tap
Recycled water supply	Dedicated outdoor gardening and irrigation taps (minimum of 2 external taps)
	Toilet
Drainage	
Drains to	**Drainage point**
Sewer	Shower/bath
	Kitchen, bathroom and laundry tub
	Pool filter backwash
	Dishwasher
	Toilet
	Washing machine
	Floor Wastes
Stormwater	Pool overflow
	Rainwater tank overflow and first flush

Figure 6. Uses and drainage points of different types of water in the Googong IWC..
Source: Queanbeyan-Palerang Regional Council (n.d.).

Figure 7. Representative connector and public safety sign associated with the purple recycled water distribution system.
Source: Queanbeyan-Palerang Regional Council (n.d.).

- **Rainwater harvesting at household level:** All residences include a rainwater tank that collects roof runoff for non-potable uses such as laundry and garden irrigation (Table 1). These tanks help reduce stormwater runoff and supplement the recycled water supply, easing demand during wet periods and adding resilience during droughts.
- **Water-sensitive urban design:** Googong's landscape incorporates nature-based solutions such as vegetated swales, retention ponds, constructed wetlands, and permeable pavements to manage stormwater. These allow rainwater to infiltrate the ground and slow runoff, filtering out sediment and nutrients before water reaches local creeks. They also reduce flood peaks, limit erosion, and provide green space and habitats for local species.
- **Smart controls and metering:** Sensors throughout the network ensure that recycled water quality and pressure are maintained, and that any anomalies (e.g., cross-connections or leaks) are quickly detected. Residences are also equipped with smart water meters that monitor potable vs. recycled water usage, helping in both billing and raising awareness of consumption patterns.

Table 1: Minimum rainwater tank sizes per dwelling type.

Dwelling type	Typical lot area (m^2)	Assumed roof catchment area (m^2)	Required tank sise (L)
Apartments, terraces, Compact lots	<300	-	Optional
Small courtyard, Medium courtyard	365	100	2,000
Large courtyard	450	125	2,000
Small traditional, Medium traditional	480	150	4,000
Large traditional, Estate home	645	200	4,000
Estate home (rural), Zone U hamlet, Zone U Talpa, E2 lots	2,000	300	10,000
Zone Y hamlets, Rural (R5), Rural APZ	15,000	300	10,000
Non-residential	Any	Any	Optional

Urban planning and policy

2002
The first plans for the Googong township are developed by Canberra Investment Corporation (CIC).

2006
The New South Wales (NSW) Minister of Planning releases the Independent Queanbeyan Land Release Inquiry, recommending Googong as the primary residential growth area for Queanbeyan. Rezoning approval is granted in line with the CIC master plan.

2008
The *Queanbeyan Residential and Economic Strategy 2031* (revised in 2015) is approved, endorsing urban release areas and supporting Googong's residential development.

2010
The *Googong Development Control Plan* is approved by the Queanbeyan City Council, establishing the planning and design of the township and legally binding the developer to deliver the Googong IWC.

2011
The Googong IWC is classified as a Major Project, streamlining approval processes while imposing stricter environmental requirements, including a comprehensive water management plan with continuous water quality monitoring.

2011
The NSW Department of Planning approves the Googong IWC Environmental Assessment, allowing construction to begin.

2012
The Queanbeyan City Council approves the Queanbeyan Development Control Plan 2012 (revised in 2022), mandating that new developments include rainwater harvesting and wastewater reuse.

2013
The Googong IWC project is officially launched with support from national and local leaders as a flagship urban sustainability initiative. Construction of water and sewer infrastructure commences in tandem with the first housing stages.

2015
Stage 1 of the WRP is concluded, treating approximately 150,000 L of wastewater from the township's first residents. The same year sees the approval of the Googong Township Integrated Water Cycle Operational Environmental Management Plan.

2016
Googong is awarded a 5-Star ("Green Star – Communities") rating by the Green Building Council of Australia — the first project in the NSW and Australian Capital Territory region.

2017
The Googong Plumbing Standard is approved, defining parameters for the installation of recycled water and rainwater harvesting infrastructure in the township.

2020
Full operation of the recycled water system begins on 1 December, following testing and commissioning. Recycled water is supplied to end-users, with the Queanbeyan-Palerang Regional Council assuming responsibility for system operation and maintenance.

2023
Stage 2 of the WRP is completed, increasing treatment capacity to 3 MLD — enough for the planned population of 18,000 residents.

Climate and environmental impacts

Mitigation: By locally treating and reusing wastewater and harvesting rainwater, the Googong IWC avoids much of the energy-intensive pumping of water and wastewater over long distances, translating into a lower carbon footprint. A 2016 study found that decentralised, non-potable water reuse can reduce greenhouse gas emissions by up to 29% in peri-urban areas.

Adaptation and resilience: The Googong IWC significantly enhances resilience to drought and extreme weather. During water shortages, the township can meet non-potable demand using recycled water and stored rainwater, avoiding the strict restrictions faced by neighbouring areas. Its integrated stormwater system manages runoff volume and flow, reducing flood risks and erosion during intense rainfall.

Other environmental benefits:

- The IWC was designed to protect local ecosystems and safeguard Googong Dam. This is accomplished by reducing the volume and improving the quality of water discharged into the dam.
- Water-sensitive urban design reduces pollutant loads in runoff, improving the quality of nearby creeks and rivers.
- Recycled water sustains green spaces, covering 32% of the townships area, helping to support biodiversity.
- A 52 ha conservation area has been established for the vulnerable Pink Tail Worm Lizard, backed by AUD 1 million in funding (approx. EUR 559,000).

Financing and funding

Capital investment:

- The AUD 133 million (EUR 74.2 million) capital investment in the Googong IWC was primarily financed by the township developers, Peet Limited and Mirvac.
- A Federal Government Grant of AUD 5.1 million (EUR 2.9 million) was awarded to the IWC for its innovative water management approach.
- A Voluntary Planning Agreement provided incentives, with developers delivering critical infrastructure in exchange for development rights.

Ownership, operations and maintenance: Upon completion, ownership of the IWC assets (the treatment plant and pipelines) were transferred to the Queanbeyan-Palerang Regional Council, which owns and operates the system as a public utility. Operational costs are covered through a user-pays model via water billing.

- **Billing and cost recovery:** Residents receive two water meters (potable and recycled) and are charged separate tariffs. Recycled water is priced lower to incentivise its use, supporting cost recovery and reducing demand on potable supply. The model enables financial sustainability through blended water rates.
- **Support and handover:** In the early years of the project, operations were supported by private contractors under service and warranty agreements, ensuring a smooth transfer of expertise to staff of the Queanbeyan-Palerang Regional Council.

Cost-benefit analysis:

- **Long-term savings and avoided costs:** The Googong IWC's upfront investment in local water resilience helps to delay, or potentially eliminate, the need for costly regional water supply expansions, reducing future infrastructure burdens on governments and ratepayers.

- **Market value and developer returns:** The water recycling scheme has been well received by the community and played a significant role in attracting many residents to purchase lots in the township. The “water-sustainable” branding of the development added market appeal to Googong, likely increasing property demand and enabling developers to recoup some costs through higher lot values.
- **Drought impact mitigation:** By securing a resilient water supply, the system shields the community from costly disruptions during droughts, which are expected to intensify under climate change.

Stakeholder engagement and social inclusion

Public-private collaboration: The Googong IWCwas a product of strong collaboration between the private sector (Peet Limited and Mirvac), the Queanbeyan-Palerang Regional Council, and national authorities. A project steering group comprising engineers, planners, and community representatives guided the development of the integrated water strategy.

Community consultation and buy-in: Stakeholder engagement began during the 2010 environmental assessment phase through public exhibitions and community sessions, allowing residents, future buyers, and interest groups to review IWC plans and raise questions about safety and odour. The community has been highly receptive, with the recycled water system cited as a key reason for choosing to live in Googong and a source of ownership and pride.

Education and social inclusion: Significant efforts are made to familiarise the community with the new system:

- Every household receives a detailed booklet titled **"A guide to everything you need to know about recycled water in Googong"**, covering good practices for using non-potable water from purple pipes.
- Social media, newsletters, and city-wide signage are used to communicate updates about the plant to a broader audience.
- Site tours and workshops are held to educate residents on how the treatment plant and rainwater tank systems work.
- Campaigns emphasise health and safety, ensuring even vulnerable groups (e.g., children and the elderly) understood that recycled water is not for drinking.
- Local schools integrated the Googong water cycle into their curriculum, turning children into water-saving ambassadors at home.

Water circularity knowledge exchange and network: Given strong interest from urban planners and water professionals both in Australia and internationally, the project team has hosted site visits for delegations from water-scarce regions and shared insights at global conferences. These efforts have supported knowledge exchange and helped position Googong within a broader network of innovation on water resilience and circularity.

Contributors to success

Values:
The Googong IWC was guided by the principle that water is a scarce, valuable resource that must be managed efficiently and reused. New developments were expected to offset, not add to, existing water demands through local recycling. Education and transparency helped build public understanding, acceptance, and ultimately, communal pride in the system.

Connections:

1. **Physical connections:** The project connected elements of the urban water cycle that are usually separate — linking homes to a local recycling plant, linking stormwater management to urban design, and linking wastewater outputs back to water supply input — thereby forming a closed-loop system.
2. **Social connections:** The partnership between private developers, local council, state government agencies (planning, health, and environment), and eventually the residents themselves was enabled by consistent public engagement and communication; building trust and shared ownership was crucial. Googong's experience also connected with broader knowledge networks, drawing from previous sustainable communities (e.g., Olympic Village projects cited in its design) and now serving as a model for other cities.

Investments:

1. **Long-term vision:** Decades-long planning enabled a phased rollout that withstood extended approval processes.
2. **Regulatory certainty:** Strong public sector engagement and policy support reduced investment risk and guaranteed system adoption.
3. **Community engagement:** Investment in education and communication built public trust and ensured effective system use.
4. **Market value:** Clear sustainability messaging boosted buyer interest, supporting strong property sales and return on private investment.

Replicability

The Googong IWC offers a practical and scalable model for circular urban water systems, particularly in inland, water-stressed regions. Its success stems from long-term planning, decentralised infrastructure (e.g., dual-pipe networks and local recycling), and a supportive policy environment — all of which can be embedded into urban growth strategies with strong public–private coordination.

While designed for a new development, Googong's core elements are adaptable to existing cities. Building codes can require dual plumbing in new constructions, while neighbourhood-scale reuse and rainwater harvesting can be integrated into urban renewal projects. Clear regulations, reliable investment frameworks and early community engagement were key to building trust and ensuring long-term viability.

These insights are especially relevant for Morocco, where rapid urban expansion and growing water scarcity demand more resilient approaches to water infrastructure. Developments in arid inland regions — such as Mohammedia or emerging suburban zones — could mandate integrated water reuse systems from the outset, reducing pressure on centralised infrastructure. The Googong public–private model is also transferable: developers financed water infrastructure as part of the greenfield development package, while the municipality took over long-term operations — an approach that could be adapted to Moroccan urban governance structures.

Strong communication and community engagement are also key lessons from the Googong that are applicable to Morocco. The country's long-standing tradition of rainwater harvesting provides a foundation for public trust, which can be renewed through modern communication campaigns and school programmes.

Googong provides a scalable blueprint for circular water communities that can be tailored to the Moroccan context — merging modern infrastructure with local values of conservation and resilience.

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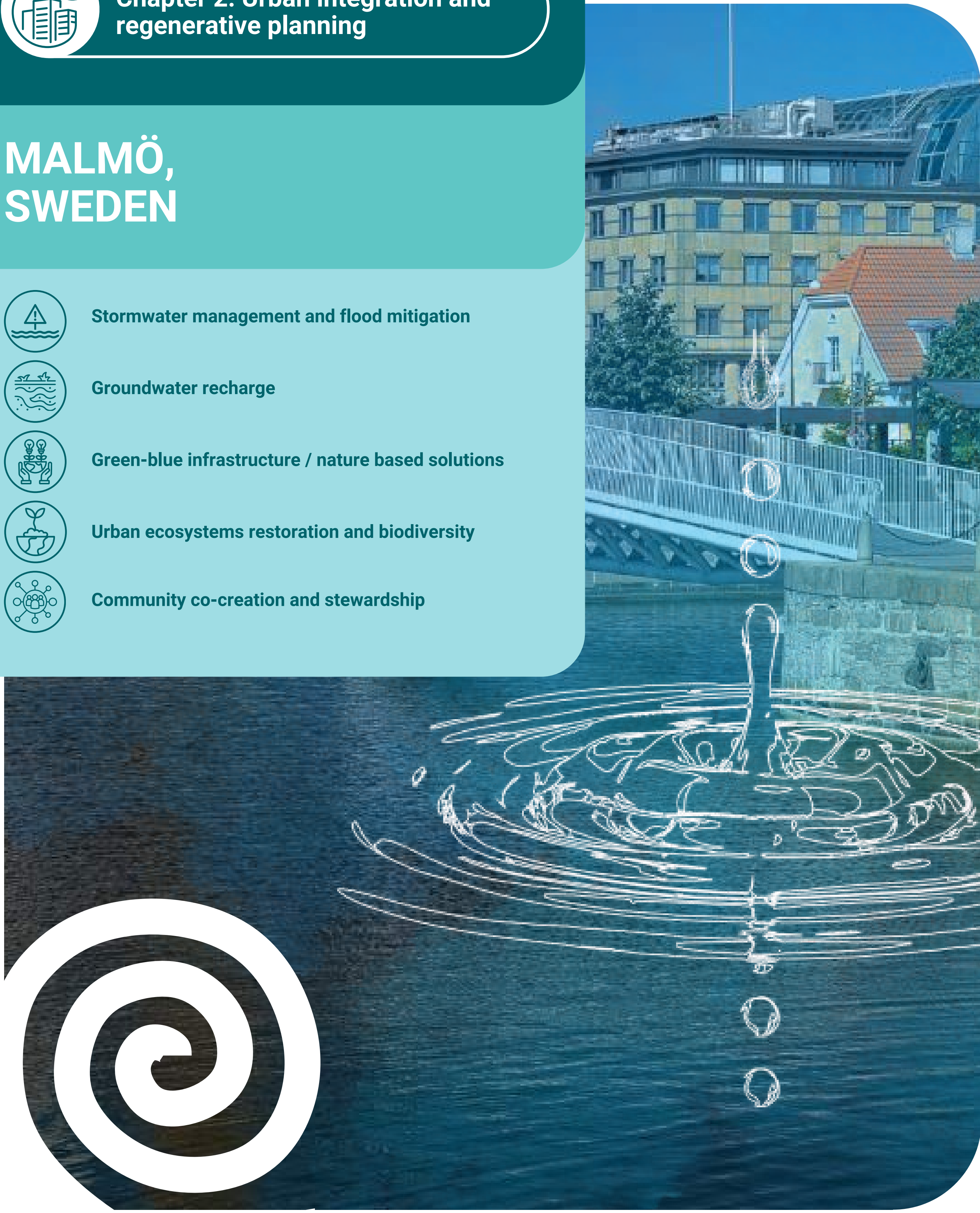
Chapter 2: Urban integration and regenerative planning

MALMÖ, SWEDEN

- Stormwater management and flood mitigation
- Groundwater recharge
- Green-blue infrastructure / nature based solutions
- Urban ecosystems restoration and biodiversity
- Community co-creation and stewardship



City overview

Population: 365,644 (December, 2024)
Climate: Temperate oceanic, with mild/humid summers and cool/wet winters (Köppen Cfb)
Rainfall: 673 mm/year (moderate)
Water-related risks:

- **Urban flooding** caused by intense rainfall and inadequate, outdated sewerage infrastructure, leading to property damage, wastewater runoff, pollution of water bodies, and negative impacts on ecosystems and public health.
- **Changing precipitation patterns due to climate change,** with Malmö projected to see an increase in rainfall during the winter as well as increased water scarcity during summer.

Case study overview

Initiative name: Ekostaden Augustenborg
Location: Malmö, Sweden
Period:

- 1998–2002: Initial implementation
- 2002–Present: Ongoing operation as a living lab

Type of initiative: Rainwater Harvesting, Stormwater Management & Flood Mitigation
Scale of initiative: District-scale
Project leads: City of Malmö in partnership with the Malmö Municipal Housing Company (MKB), VA-Verket (municipal water utility), local residents, and academic institutions
Project objectives: Redevelop a declining industrial neighborhood into an ecologically healthy, water-resilient district by integrating sustainable water management systems that mimic natural hydrological cycles, thereby reducing urban flooding and run-off and enhancing water circularity.

Main interventions

- **Open stormwater management system:** Installation of a sustainable urban drainage system, comprising 6 km of open water channels and 10 retention pods, draining 40% of the 33 ha area.
- **Green roofs and nature-based solutions:** Use of vegetation for decentralised stormwater control:
  - Establishment of 11,000 m² of green roofs on new and existing buildings, including the 9,000 m² Botanical Roof Garden located atop the Scandinavian Green Roof Institute, intercepting approximately 50% of total annual runoff.

    - Installation of 3-4 cm substrate and drought resistant succulent vegetation on almost all roofs.
- **Energy-efficient buildings:** Renovations carried out in 1,600 public rental apartments (89% of the total housing in the area) to improve energy efficiency, including upgrades to insulation and heating systems.
- **Solar power:** Installation of 450 m2 of solar panels and photovoltaic systems, including on rooftops.

Main outcomes

- **Flood mitigation and stormwater management:** At present, 90% of stormwater from rooftops and other impervious surfaces is led to the open stormwater management system, reducing total annual runoff volume by approximately 20% and enhancing operational resilience against sewer overflows.
- **Green space and biodiversity:** A total of 30 gardens/parks have been restored using indigenous trees, attracting new wildlife and increasing local biodiversity by 50%.
- **Energy efficiency:** Building renovations have increased energy efficiency by 35%, leading to a 20% reduction on associated carbon emissions in the neighborhood.
- **Renewable energy:** At present, renewable energy accounts for 80–85% of energy used for district heating and 10–15% of the hot water produced.
- **Ecologically healthy, resilient, and attractive neighborhood** for almost 4,000 residents, reducing tenancy turnover by 50%.

Total cost

SKR 200 million (EUR 17.8 million)

Project

Context

The Augustenborg neighborhood occupies a low-lying and flood-prone area of Malmö, Sweden's third-largest city, located on its southern coast. Originally developed in the late 1940s as a public housing project, Augustenborg began experiencing serious water-related challenges by the 1980s, resulting from outdated drainage systems and frequent surface flooding during heavy rains. Malmö's sewer system often became overwhelmed, leading to sewer overflows, water damage, and declining ecological health. As the sustainable urban regeneration agenda in Malmö gained momentum in the 1990s, Augustenborg was chosen as a pilot site for testing nature-based solutions to address its growing water management issues.

Project description

In 1998, the City of Malmö launched the Ekostaden Augustenborg initiative, which has since become recognised as a pioneering eco-district in Malmö, transforming the neighborhood from a polluted, flood-prone area into a model of sustainable urban living. This was achieved through the integration of sustainable urban drainage systems, circular water flows, green infrastructure, nature-based solutions, and community engagement to reduce flood vulnerability, enhance resilience, and improve quality of life in a socially inclusive and ecologically sound way.

One of the project's core features is a decentralised open stormwater system, comprising 6 km of visible canals and 10 retention ponds that collect and slow surface runoff from roofs, roads, and courtyards. Over 11,000 m2 of green roofs were installed to absorb stormwater, reduce runoff, and provide insulation. Permeable pavements and vegetated channels further allow water to soak into the ground, supporting groundwater recharge. These systems mimic natural, localised water cycles, and have reduced annual runoff by approximately 20%. This reduction in runoff helps prevent flooding during heavy rainfall, reduces pressure on Malmö's sewer network, and mitigates the pollution of water bodies.

Together, these interventions have made Augustenborg more climate-resilient, improved local biodiversity, and restored water as a visible and valued part of the neighborhood. The project's innovative approach has been widely recognised, receiving numerous awards — including the World Habitat Award, UN-Habitat Scroll of Honor, and Malmö's Urban Development Award — underscoring its success in combining ecological innovation, social inclusion, and climate resilience at the neighborhood scale. Augustenborg offers valuable insights for Moroccan cities as a reference for urban adaptation to increased rainfall and flood risks.

Circularity technologies and solutions

- **Disconnection from centralised sewer system:** This approach reduces the volume and peak flow of stormwater entering the centralised sewer network, mitigates sewer overflows, and ensures that nearly all stormwater is managed locally, relieving pressure on regional wastewater treatment works and reducing pollution risks.
- **Sustainable urban drainage systems:** The project established 6 km of open water channels and 10 retention ponds, along with wetlands and vegetated swales (Figure 1). These features slow, store, filter, and treat stormwater locally before any surplus is released into the conventional sewer system. Overall, these interventions reduced rainwater runoff by 90%, reducing sewer loads and improving water quality. Today, only a negligible volume of stormwater enters the sewer network, which almost exclusively drains wastewater.
- **Green roofs:** The project installed 11,000 m2 of green roofs on new and existing buildings, including the 9,000 m² Botanical Roof Garden. By absorbing rainfall, these green roofs intercept approximately 50% of total annual runoff, further reducing pressure on centralised storm- and wastewater infrastructure and the risk of floods, while also providing additional green space.
- **Waste circularity:** The area achieves a recycling compliance rate above 50%, supported by 13 waste separation stations, including consistent food waste composting.

Figure 1. Illustrated plan of EkostadenAugustenborg, showcasing part of the open stormwater system. Source: Boverket (2023).

Urban planning and policy timeline

The project was guided by Malmö's comprehensive sustainability goals, incorporating participatory planning processes and aligning with national environmental objectives.

1997
The idea for an "eco-city" in Augustenborg is first promoted by local actors — including the City of Malmö Service Department, MKB, and Augustenborg School — in response to recurring urban flooding and social decline.

1998
The Ekostaden Augustenborg project is formally launched with funding from Sweden's Local Investment Programme (LIP) and the EU LIFE Programme, coordinated by the City of Malmö and MKB.

1999
The project establishes 6 km of open stormwater channels and 10 retention ponds, integrated into the neighborhood, accompanied by the amendment of spatial planning procedures and the design of green spaces.

2001
The Botanical Roof Garden is opened atop the Scandinavian Green Roof Institute as a demonstration and educational center for sustainable roof infrastructure.

2002-2005
The Augustenborg experience serves as the basis for the development of Malmö's Green Space Factor (Grönytefaktor), later adopted as a planning requirement for new developments in the city.

2006-2010
New environmental strategies are launched to integrate sustainable water management into Malmö's urban planning framework, based on the Ekostaden Augustenborg project.

2016
MKB begins constructing the Greenhouse Augustenborg, a 14-story, 56-unit passive-house apartment building featuring multiple ecologically sensitive features: solar panels, green roofs, a communal roof garden and greenhouse, cultivation balconies, cargo-bike sharing, smart waste sorting, and individual energy and water metering.

2017-Present
The neighborhood continues to serve as a national and international reference for stormwater and cloudburst management, influencing Sweden's National Strategy for Climate Adaptation and Malmö's Cloudburst Management Plan. The district continues to host study visits, inspire research, and inform municipal policy.

Climate and environmental impacts

Mitigation:

- A total of 450 m² of solar panels, complemented by the introduction of small-scale wind power in 2009, supplies 10–15% of the energy required to meet local water heating needs. Overall, energy consumption for the heating of buildings and water decreased by 25%. As a result of these renewable energy sources and the implementation of energy efficiency measures, the neighborhood's carbon emissions fell by more than 20%.

Resilience and adaptation:

- The open stormwater channels and retention ponds, combined with other nature-based solutions, manage 90% of rainfall on-site, reducing flood risk and sewer overflows. This decentralised, gravity-based system remains functional during heavy rainfall events, and does not depend on pumps or external power.

Biodiversity and environment:

- More than 11,000 m² of green infrastructure — such as green roofs, wetlands, and permeable surfaces — have been added to the neighborhood, creating habitats that have increased local biodiversity by 50%, improved air quality, and contributed to cooling in the dense urban environment.

Financing and funding

Investment costs: The total investment of SEK 200 million (EUR 17.8 million) was secured through a multi-level, collaborative financing model:

- **National government – LIP:** SEK 29.3 million (EUR 2.63 million) distributed in two rounds (1998 and 2002–2005) to co-finance infrastructure operational costs (Table 1).
- **City of Malmö – MKB:** SEK 100 million (EUR 8.97 million), including SEK 70.5 million (EUR 6.32 million) as the municipal contribution to the LIP grant.
- **City of Malmö – primarily through VA-Verket:** SEK 55 million (EUR 4.93 million).[1]
- **European Union – EU LIFE Programme:** SEK 7 million (EUR 0.63 million) to support the development of the Botanical Roof Garden.
- **National government – Kretsloppsmiljarden:** SEK 7 million (EUR 0.63 million) to match funds received from the EU LIFE grant.
- **Private sector:** Private developers also contributed financially by aligning new buildings with the practices of Augustenborg and the requirements of the subsequent Green Space Factor.

Operations and maintenance (O&M) costs: SEK 150,000 (EUR 13,450) per year

- The annual O&M costs Augustenborg's open stormwater and green infrastructure system is double that of a conventional sewerage system, largely because of tasks like clearing debris and repairing granite channels.
- The O&M of Augustenborg's open stormwater and green infrastructure system is primarily funded via the City of Malmö's municipal budget, MKB's rental income, and VA-Verket's water rates.

Cost-benefit analysis: The relatively high investment and O&M costs of the project are outweighed by its significant economic and environmental:

[1] The blue-green stormwater management infrastructure was primarily funded by the City of Malmö through MKB and VA-Verket. Precise figures and sources for the remaining amount funded by the City of Malmö are unavailable.

- **Flood resilience:** Augustenborg has seen an estimated 50% reduction in flood-related damage costs. For example, during Malmö's 2014 cloudburst (with over 100 mm of rainfall), which caused more than SEK 600 million (EUR 53.83 million) in city-wide damages, Augustenborg remained unaffected.
- **Property value and quality of life**: Collectively, the interventions of Ekostaden Augustenborg have increased property values and overall levels of tenant satisfaction. As a result, the tenancy turnover rate in the areas has decreased by 20%.
- **Economic activity:** The initiative spurred local entrepreneurship, leading to the creation of new jobs and establishment of small and medium enterprises such as Watreco (offering stormwater solutions), the Green Roof Institute, and Skåne's Car Pool.

Table 1 : Allocation of funding from LIP grants and other sources across components of the Ekostaden Augustenborg initiative over two funding rounds (1998 and 2002–2005).

Cost items linked to Ekostaden Augustenborg (actual amount spent from final audits between parentheses)	*Total cost, thousands SEK*	*LIP grants, thousand SEK*	*Other financing (mainly MKB), thousands SEK*
First grant round (1998)			
Project management, environmental management, quality assurance, project design	11,333 (11,458)	3,400 (3,400)	7,933 (8,058)
Local stormwater management	7,333 (10,115)	2,200 (2,200)	5,133 (7,915)
Local waste management	8,500 (8,638)	2,550 (2,550)	5,950 (6,088)
Local electric transport (trackless train)	7,333 (9,894)	3,300 (3,330)	4,033 (6,594)
Environmentally adapted renovation of yards, squares, and other public spaces	11,333 (11,418)	3,400 (3,400)	7,933 (8,018)
Resource management	6,333 (8,112)	1,900 (1,900)	4,433 (6,212)
Environmentally adapted redevelopment of a media and cultural center	1,212 (1,570)	400 (400)	812 (1,170)
Environmentally adapted regeneration of school grounds and parks	3,125 (7,298)	2,000 (2000)	1,125 (5,298)
Restoration of cultural and historical heritage (part of energy project)	15,000 (16,930)	4,500 (4,500)	10,500 (12,430)
Operation and management of Ekostaden	500 (500)	200 (200)	300 (300)
Second grant round (2002–2005)			
Energy-efficient building features (installation of individual metering units)	16,575 (3,096)	4,973 (929)	11,602 (2,167)
Solar panels, solar cells, energy recycling, energy recovery from ice rink	22,500 (6,266)	3,375 (2,538)	19,125 (3,788)
"Living and Working in an Eco City" education campaign	3,350 (2,370)	1,525 (1,185)	1,825 (1,825)
Electric carpool (not implemented)	64 (0)	32 (0)	32 (0)
Quality control, coordination, evaluation	3,100 (2,439)	1,178 (927)	1,922 (1,512)

Source: Adapted from Månsson & Persson (2021; 57–58).

Stakeholder engagement and social inclusion

Collaboration with key stakeholders:
- A cross-sectoral team of city officials, school representatives, and residents shaped the early vision for Ekostaden Augustenborg.
- Throughout the subsequent implementation phase, partners included schools, local businesses, universities, and private companies, who were particularly involved in launching the Green Roof Institute, a network and learning hub for green-blue infrastructure solutions.

Community participation and co-creation:
- Around 20% of Augustenborg residents, including schoolchildren, participated in public meetings, planning workshops, and educational events.
- These residents influenced the design of green spaces and stormwater systems.
- A special needs advisor supported inclusive and accessible design.

Education and awareness:
- Study circles, school programmes, and events promoted awareness of green roofs, stormwater management, and energy efficiency.
- Children engaged in rooftop gardening, composting, and sustainability campaigns.
- A local windmill, solar heating, and green roofs were installed at schools, allowing youth to see and learn about these types of infrastructure.

Capacity-building and employment:
- Residents helped maintain green spaces and water systems, building local skills and promoting long-term community involvement.
- The project spurred entrepreneurship and job creation, such as through the Green Roof Institute, a carpool cooperative, and Watreco AB. Consequently, unemployment dropped from 30% (1998) to 6% (2002).

Civic empowerment and social integration:
- With 65% of residents coming from migrant backgrounds, Ekostaden Augustenborg required inclusive strategies to address segregation and social fragmentation.
- Early engagement built trust, increased social cohesion, and boosted voter turnout from 54% (1998) to 79% (2002).

Knowledge-sharing and replication:
- Augustenborg became a living demonstration site for sustainable urban regeneration.
- Over 15,000 visitors have visited the area since the project began.


Source: City of Malmö (2020)

Contributors to success

Values:

- The project adopted water resilience as a core principle of urban regeneration, treating stormwater as a resource rather than a risk.
- Activities embraced decentralised, nature-based systems and blue-green infrastructure that deliver both flood protection and community amenities.
- Community engagement and education were embedded within the project from the outset, with residents acting as co-creators and long-term stewards of their environment.

Connections:

1. **Physical connections:** A visible, open network of canals and basins connects rooftops, roads, and green spaces, supporting infiltration, reducing runoff, and relieving pressure on the sewer system.
2. **Social connections:** Strong local networks were built through participatory planning, school involvement, and continuous dialogue. The Green Roof Institute and similar initiatives helped share knowledge and inspire replication in other Malmö districts and beyond.

Investments:

- Involvement of multiple actors, especially VA-Verket and MKB, in the funding model and promotion of financial incentives through increased land value and rental income.
- Multi-level funding from the EU, national and local governments, and public companies.

Replicability

Since its inception in 1998, Ekostaden Augustenborg has earned global acclaim as a cost-effective, replicable model of urban water resilience. Its innovative open-water system and deep community involvement have received numerous national and international awards, inspired similar projects in Malmö's Bo01 and Sege Park districts, and prompted study visits and pilot schemes in cities ranging from Copenhagen to Singapore.

In Morocco, where cities like Casablanca and Rabat face both flash floods and chronic water scarcity, Augustenborg's approach offers a blueprint for resilience and circularity. Green roofs on residential blocks, neighborhood-scale retention basins, and constructed wetlands can capture most stormwater for controlled aquifer recharge, irrigation, or reuse, while reducing flood peaks.

In coastal Tangier and historic Tétouan, where sudden downpours overwhelm aging sewer infrastructure, decentralised rain gardens and bioswales can relieve drainage networks. Embedding participatory planning through local committees and school programs ensures community-driven design and long-term stewardship. Finally, mobilizing multi-level financing schemes and shared public–private management can lay the foundation for scalable, durable green-blue infrastructure across Moroccan urban districts.

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Chapter 2: Urban integration and regenerative planning

TUNIS, TUNISIA

Stormwater management and flood mitigation

Green-blue infrastructure / nature based solutions

Urban ecosystems restoration and biodiversity

Public-private and multilevel governance models

City overview

Population: 2,545,030 (2025)
Climate: Hot, semi-arid climate (Köppen BSh) bordering a hot-summer Mediterranean climate (Csa), with dry, hot summers and mild winters
Rainfall: 444 mm/year (moderate)
Water-related risks:

- **Contaminated water:** North Lake's slow water renewal rate (high lake retention time) and the continuous inflow of nutrient-rich wastewater have caused severe eutrophication, disrupting its ecological balance and significantly degrading water quality over time.

Case study overview

Project name: North Lake of Tunis Rehabilitation and Urban Development Project
Location: Tunis, Tunisia
Period:

- 1983-1988: Lake rehabilitation
- 1989–2030: Redevelopment and urbanisation

Project type: Aquatic ecosystem restoration
Project scale: Neighborhood/district
Main project leads: Al Buhaira Invest (previously Société de Promotion du Lac de Tunis), a joint venture between the public sector (The Government of Tunisia) and private sector (Dallah El Baraka Group)
Project objective: To clean the Tunis North Lake watershed, remove debris, improve water quality, restore the shoreline, redirect urban expansion to protect agricultural land, and support balanced economic growth through the planning and development of a new sustainable city district.

Main interventions

- **Sediment removal:** Organic-rich and polluted sediment was dredged from the lagoon's northern and western areas.
- **Water discharge control:** All direct wastewater discharges into the lagoon were stopped. Presently, only urban stormwater runoff is permitted to enter the lagoon as a measure to prevent flooding. Winter freshwater runoff from the city of Tunis is released via underground point sources.
- **Water diversion:** An east–west dam with tide-controlled gates was constructed to improve lagoon-sea exchange and reduce water residence time to approximately 22–27 days.
- **Shoreline realignment and stagnation prevention:** Shorelines were modified and backfilled to remove stagnant areas and promote even, consistent water circulation across the lake.

- **Rainwater retention basin:** A 9 ha shallow basin was constructed near the eastern shore to retain stormwater and protect Kram City from flooding. Excess water is occasionally released into the channel at low tide.
- **Ecological and urban renewal:** The project rehabilitated degraded suburban land into an environmental and urban development asset, combining ecological and economic goals.

Main outcomes

- **Lake restoration and reconstruction:** The project removed contaminated sediment, including approximately 1 million m³ of organic sludge, reshaping the lake's banks.
- **Structural transformation:** The surface area of the lake was reduced from approximately 28 km² to 24 km², while the average depth increased from 0.9 m to 1.5 m. A new 22 km shoreline was constructed, with a total embankment area of 7 km².
- **Energy generation:** A floating power plant with a capacity of 200 kW commenced operation in June 2022 (Figure 1). With a surface area of 2,500 m², it will supply 265 MWh annually and contribute to reducing the country's CO_2 emissions by 120 t.
- **Land reclamation:** A total of 1,300 ha of developable real estate were established, including 500 ha reclaimed as part of the cleaning project.
- **Settlement:** Phase 1 and 2 of infrastructure planning (1996–2001) initially covered approximately 60 ha, with the broader goal of 280 ha of total built area to accommodate a population of 120,000.

Figure 1. Floating solar plant on the Lake of Tunis.
Source: Kapitalis.com

Total cost

TND 515 million (EUR 152 million)

Project

Context

The Lake of Tunis — a natural lagoon situated in the Tiunisian capital of Tunis — has historically served as the city's natural outlet for urban and industrial wastewater, along with surface runoff from rainfall. This high inflow of waste- and stormwater, combined with the lake's low water circulation rate, has led to a steady decline in water quality. Moreover, the continuous discharge of enriched, untreated wastewater, particularly high in nitrogen and phosphorus, into a relatively stagnant, shallow, and sun-exposed aquatic environment has disturbed the lake's ecological equilibrium. These factors have collectively resulted in severe eutrophication, affecting the health of the ecosystem as well as its surrounding environment.

Project description

In response to steady ecological degradation, beginning in the 1980s, the Société de Promotion du Lac de Tunis (SPLT) was formed via a public-private partnership (PPP) with the goal of restoring and redeveloping 1,327 ha on the northern bank of the lagoon. North Lake underwent major rehabilitation, including wastewater diversion, shoreline clean-up, and the creation of a regulated hydrological regime (Figure 2). The ecological restoration of the lake and its shoreline entailed extensive land reclamation, enabling large-scale urban development of the surrounding land through a comprehensive master plan (Figure 3) and public-private joint venture between SPLT and Dallah El Baraka, a Saudi investment group. By reclaiming the site's ecological, social and economic value, the master plan aims to transform the space for environmental stewardship, housing, economic growth, and public amenities.

Ultimately, the project is expected to accommodate approximately 120,000 residents and create 140,000 employment opportunities. Green spaces dedicated to parks and other recreational areas (excluding private gardens) will cover nearly 20% of the land, providing roughly 20 m² of green space per inhabitant. The project demonstrates how the restoration of a water body can serve as a foundation for improved ecological health as well as sustainable urban expansion.

Figure 2. North Lake after rehabilitation, highlighting improved water quality and recreational spaces. Source: Al Buhaira invest

Figure 3. Master plan of the "La Perle du Lac" project.
Source: Arab Urban Development Institute (n.d.).

Circularity technologies and solutions

- **One-way water circulation system:** A large portion of the lake was dredged to increase its depth and improve water circulation. Additionally, the project implemented a one-way water circulation system driven by tidal movements, featuring inlet and outlet points with one-way flap gates at the Khereddine Canal, a
- **Dike installation:** An 8.2 m long and 5–8 m wide central separation dike was installed, dividing the North Lake into two sections (Figure 4). This structure directs water to flow through the entire lake before being discharged into the sea. The increased rates of water circulation have decreased lake retention time and led to faster renewal over a period of 22–27 days, depending on wind direction and speed.
- **Shoreline modification:** The shorelines were reshaped and filled in to eliminate stagnant water zones and promote consistent water circulation.
- **Runoff management:** The project halted all wastewater discharges into the lagoon, permitting only urban stormwater runoff to enter the water body in order to prevent flooding. During winter, stormwater runoff from Tunis is discharged mainly as point sources along the northern and eastern shores via underground networks, and as diffused, nonpoint sources in the southern basin.
- **Stormwater basin:** A shallow basin of 9 ha, with an average depth of 1 m, near the lagoon's eastern shore is specially managed to collect rainwater runoff and protect Kram City from flooding. Excess water from this basin is occasionally released into the channel at low tide.

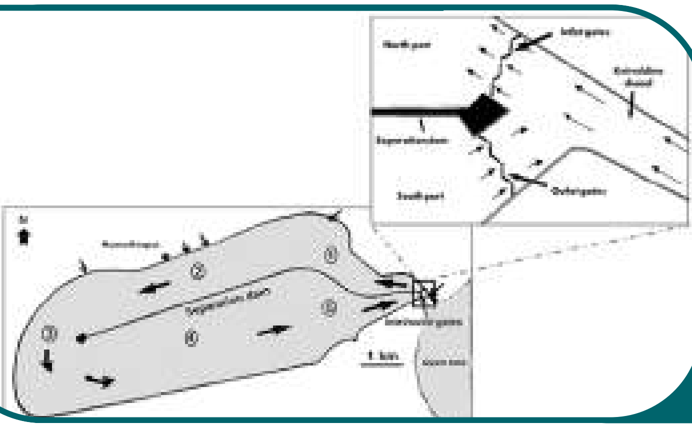

Figure 4. Diagram of the separation dam and resulting changes in water circulation through North Lake. Source: Trabelsi-Bahri et al. (2013).

Urban planning and policy timeline

1974
The National Office of Sanitation is established to manage and treat urban wastewater and reduce pollution in urban areas.

Source: Al Buhaira Invest

1975
Tunisia's sanitation policies largely concentrate on wastewater management in coastal areas favored by tourists.

Source: Al Buhaira Invest

1980
SPLT is formed via a PPP to restore and redevelop North Lake.

1985-1988
Restoration work on the lake was initiated based on a hydrodynamic and ecological model, with the aim of rehabilitating an environment that had long served as a receptacle for wastewater and stormwater from the northern districts of Tunis

1989
Thereafter, the SPLT began the gradual urban development of the lake's banks, with a land reserve estimated at 1,300 hectares.

Urban development around the North Lake.
Source: Al Buhaira Invest

Source: Al Buhaira Invest

2002
Strategies to enhance and activate the northern shore of North Lake are adopted following a sub-concession agreement granted to SPLT by the state.

2009-2012
A study of the lake is conducted with related ministerial departments (Equipment, Tourism, Environment, and Municipalities).

2023
Al Buhaira Invest receives tenders for public-space planting, green irrigation systems, and stormwater infrastructure maintenance.

Climate and environmental impacts

Mitigation:

- The project promotes sustainable, eco-friendly mobility by prioritizing cycling lanes to reduce car use. Strategically located near the country's largest international airport, La Perle du Lac offers direct access to major routes into the city center by public transport and other mobility options. These non-motorised and public forms of transport help to reduce greenhouse gas emissions from reliance on private vehicles.

Adaption and resilience:

- Cleaning the lake's drainage basin and removing waste have improved water quality and restored the banks, resulting in natural water renewal through tidal movements. The resulting controlled water flows and reduced contamination enhance resilience to flooding and pollution, respectively — the key climate adaptation challenges facing coastal cities.
- The project prioritises the efficient management of gas, electricity, and water. Public green spaces have been designed to improve climatic comfort by reducing the urban heat island effect. These green spaces have the co-benefits of increasing vegetation cover, improving soil permeability, and enhancing water retention, thereby optimizing irrigation systems, improving stormwater management, and decreasing the urban heat island effect (Figure 5).
- The reclamation of land within the wetland area has enabled the urban development of the lakeside into a new, spatially integrated urban district, including housing stock, employment opportunities, public facilities and recreational space along the lake shore. This allows Tunis to sustainability meet the demands of urbanisation through the creation of a healthy environment (Figure 6).

Figure 5. Rendered 3D model of public space along the shore of North Lake, with more vegetation cover and water to reduce the urban heat island effect.
Source: Archi Mag (2023).

Figure 6. Rendered 3D model of La Perle du Lac 2 as per the master plan for mixed-use development along the shore of North Lake.
Source: Arab Urban Development Institute (n.d.).

Financing and funding

Cost structure: Initially SPLT had a capital budget of TND 34 million (EUR 10 million), which was later increased to TND 44 million dinars (EUR 12,9 million). Combined investment ultimately reached approximately TND 515 million (EUR 152 million), spanning infrastructure, dredging, shoreline restoration, and urban development.

Financing sources and instruments:

- **PPP and joint ventures:**
  - The Government of Tunisia: TND 17 million (EUR 5 million) — comprising 800 ha of land and TND 3 million in direct funding
  - Dallah El Baraka Group: TND 17 million (EUR 5 million)

Cost-benefit analysis:

- **Economic benefits:** The project has delivered high socio-economic returns, including housing for 120,000 residents, 140,000 jobs.
- **Environmental benefits:** These comprise extensive green spaces, improved water quality, greater biodiversity, and enhanced flood resilience.
- **Social benefits:** Ecological restoration has driven sustainable urban growth, with significant long-term public benefits, including access to housing, employment opportunities, high-quality public space, and improved health.

Stakeholder engagement and social inclusion

Al Buhaira Invest was responsible for designing and overseeing the execution of a comprehensive development plan. Co-funding was supplied through a PPP with Dallah El Baraka Group. The implementation of the plan was carried out by a Tunisian consortium of private contractors, led by Bouzguenda Frères and Bonna Tunisie (Figure 7).

Figure 7. Overview of main public and private actors involved in the North Lake Rehabilitation and Urban Development Project.

Contributors to success

Values:
By improving water quality and restoring the aquatic ecosystem of North Lake, the project demonstrated the intrinsic value of healthy ecosystems as well as their importance to healthy and sustainable cities, such as through the release of developable land, high-quality public spaces, and improved public health.

Connections:

1. **Physical connection:** Cleaning and infrastructural interventions improved the connection between the lake and its surrounding water flows, resulting in a more circular water management system. The site's strategic location also connects it to Tunisia's largest international airport, which supports potential economic development.
2. **Social connection:** Collaborative effort among diverse public and private parties and the expertise of specialists from various fields enabled the successful development of the project, focusing on environmental restoration and high-quality urban spaces (Figure 8).

Investments:
Strategic investments from both public and private sources were critical to the project's success, enabling large-scale ecological restoration and urban development. Financial contributions from the Government of Tunisia and Dallah El Baraka Group funded vital climate-resilient interventions, including water circulation systems and land reclamation ensuring long-term environmental and economic sustainability.

Replicability

This project demonstrates that long-term investments in water quality, sediment removal, and engineered hydrological controls can effectively rehabilitate degraded aquatic ecosystems. By aligning environmental restoration with urban expansion, other rapidly growing cities facing water pollution challenges can replicate this framework to enhance resilience, foster economic development, and improve quality of life.

In Morocco, several lakes and wetlands located near cities, such as Marjat Al Fawarat in Kenitra, are threatened by sprawling urban development and pollution. Adopting a similar institutional arrangement and PPP as that employed in Tunis would potentially enable the restoration of these water bodies alongside the sustainable urban development to accommodate the needs of a growing population and economy.

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Chapter 2: Urban integration and regenerative planning

ZENATA ECO-CITY, MOROCCO

- Rainwater harvesting and reuse
- Stormwater management and flood mitigation
- Green-blue infrastructure / nature based solutions
- Urban ecosystems restoration and biodiversity
- Public-private and multilevel governance models

City overview

Population: Greater Casablanca has a population of 4,012,310 (2025). (The population of Zenata is expected to reach 300,000 inhabitants by 2050.)
Climate: Hot-summer Mediterranean climate (Köppen Csa)
Rainfall: 408 mm/year (semi arid)
Water-related risks:

- **Drought and water scarcity:** Zenata lies in a region increasingly affected by aridification and recurring droughts, which now occur on average every three years. The area previously depended on the Massira Dam, whose water level has dropped to just 2.3% of its total capacity. This is driven by declining rainfall, shorter snowfall seasons, and rising temperatures, all of which reduce inflow to key dams.
- **Inadequate drinking water access and quality:** Many residents in urban and peri-urban areas rely on unsafe water sources such as shallow wells, overpriced private water vendors, or communal standpipes. To meet their sanitation needs, most households rely on cesspits or substandard septic tanks, increasing the risk of groundwater contamination.
- **Coastal flooding:** In the last 20 years, the Casablanca-Mohammedia coastal corridor has faced frequent flooding, leading to substantial damage in coastal communities from overtopping and overflow events. Coastal aquifers are severely threatened by seawater intrusion, rising salinity, and nitrate pollution due to groundwater overextraction and reduced recharge, degrading both water quality and availability.
- **Contaminated seawater:** Untreated wastewater from eastern Greater Casablanca is discharged through seven outfalls into the Atlantic Ocean, threatening marine water quality and public health by spreading harmful bacteria, viruses, and parasites, especially impacting swimmers and fishermen.

Case study overview

Project name: Zenata Eco-City
Location: Zenata, Greater Casablanca, Morocco
Period: 2006–Present
Project type: Integrated water-sensitive urban planning
Scale of initiative: Neighborhood/district
Main project lead: Société d'Aménagement Zenata (owned by Caisse de Dépôts et de Gestion du Maroc)
Project objective: Address the housing shortage and urban development challenges in Casablanca through an eco-city model that integrates water-sensitive planning, ecological corridors, and natural cooling systems to enhance climate resilience, restore the urban water cycle, and support inclusive growth.

Main interventions

- **Water-sensitive urban design:** A surface water network and landscaped retention basins collect and filter rainwater for partial reuse. Wastewater is collected, treated and discharged through a 2.2 km long marine outfall designed to harness the ocean's natural dilution and biodegradation capacity.
- **Drinking water supply:** Drinking water is provided by the Tit Mellil reservoir, fed by existing water supply systems of the National Office for Potable Water.
- **Ecological corridors:** Large-scale green infrastructure, including 470 ha of green space and coastal parks (30% of the city), function as ecological corridors, connecting urban and natural systems.
- **Integrated sewage and sanitation infrastructure:** A centralised sewage system, spanning 800 ha, forms the backbone for sanitation across the city.
- **Natural cooling system:** The eco-city's open-grid design harnesses ocean winds to provide natural cooling in summer and reduce humidity in winter.
- **Sustainable mobility network:** 44 kilometers of secure pedestrian and cycling lanes, separated from car traffic and integrated with public transit.

Main outcomes

- **Enhanced water resilience:** Rainwater harvesting and retention systems reduce runoff, which will support urban cooling, help restore the urban water cycle, and supply irrigation for green spaces.
- **Climate adaptation and mitigation:** Natural cooling design, allowing for an estimated temperature reduction of 3.6 °C, lowers energy consumption and helps mitigate urban heat island effects.
- **Wastewater management:** 2,808 m^3/h and 2,160 m^3/h of wastewater in the West and East zone respectively are managed through collectors and interceptor.
- **Improved marine environment:** The 2.2km long marine outfall will significantly improve the marine environment and reduce health risks for the local population. The most notable outcome will be achieving 'A' quality bathing waters, which are essential for the region's coastal tourism.
- **Biodiversity improvement:** A high proportion of green space aims to improve air quality, recreational opportunities, and psychological health.
- **Housing and job creation:** The eco-city master plan includes provision for accommodating 43,500 housing units, an international university, biomedical and healthcare facilities, Morocco's largest shopping mall, and an industrial park. The project is expected to create approximately 100,000 jobs, with employment opportunities primarily in manufacturing and retail.
- **Environmental stewardship and global recognition:** The project has been awarded the Eco-City Label by the French-based High Quality Environmental standard, recognizing sustainable urban design and planning.

Total cost

EUR 800 million

Project

Context

Morocco is undergoing rapid urbanisation driven by population growth and rural-to-urban migration, with its urbanisation rate projected to reach 65% by 2030. This trend, together with ongoing droughts and climate change, has intensified water challenges in urban areas, especially in ensuring a year-round supply of drinking water. The Greater Casablanca region, responsible for 18.8% of GDP and 47% of industrial jobs at the national level, is particularly affected. The area faces serious water challenges together with severe shortage of housing, amenities, and services for the middle class, leading to sprawling development on its outskirts. In response, Morocco launched a program in 2004 to build fifteen new cities by 2020, including Zenata, located in the northeast of Greater Casablanca. The Zenata project is managed by a special-purpose subsidiary of the state-owned Deposit and Management Fund (Caisse de dépôt et de gestion; CDG).

Project description

Launched as part of Morocco's national city-building program, the Zenata Eco-City spans 18.3 km2, stretching about 5.5 km along the Atlantic coast and extending nearly 3 km inland (Figure 1). Zenata boasts an integrated urban development approach centered on environmental sustainability, economic opportunity, and social inclusion. It emphasises air quality, storm- and wastewater management, transport, and especially job creation to foster an environmentally and economically sustainable and well-connected city.

A key feature of Zenata is its water-sensitive design. A surface drainage system collects rainwater and directs it into a network of landscaped retention basins, serving for stormwater management as well as the irrigation of 470 ha of green corridors, enhancing local biodiversity and regulating urban microclimates. The city's open grid layout aligns with prevailing ocean winds to support natural cooling, while groundwater recharge is supported through permeable surfaces and reduced hardscaping.

The urban master plan dedicates 31% of the area to natural spaces, 50% to mixed-use blocks — integrating housing, facilities, and commercial space — and 14% to roads and public areas. A dedicated Resettlement Policy Framework ensures equitable relocation for displaced residents. Once complete, Zenata is expected to house 300,000 people, create 100,000 jobs, and demonstrate a model for inclusive and climate-resilient urban growth in water-scarce regions.

Figure 1. Map of Zenata within its regional context.
Source: Zenata Eco-City (n.d.).

Circularity and resilience solutions

- **Water-sensitive urban design:** Zenata has separate networks for wastewater and stormwater. Stormwater is captured through surface drainage and channeled into landscaped retention basins that support groundwater recharge, irrigation of green corridors, and natural cooling. Wastewater is pre-treated, discharged offshore to protect coastal water quality.
- **Localised rainwater management:** Rainwater is gathered and partly released into the ocean through four main collectors (Figure 2). These collectors are designed to handle rainfall events lasting up to four hours. Retention basins downstream of primary collectors temporarily store rainwater from heavy storms (up to 20-year events), releasing it slowly to reduce its impact on the coast. Similar basins and collectors in two other basins manage surface runoff and prevent flooding.
- **Localised wastewater management:** Wastewater is managed via four collectors (Ha, Hb, Hc, Hd) connected to interceptors (Figure 2). The western zone’s wastewater flow of 2,808 m³/h is split among Ha, Hb, and direct connections. The eastern zone’s 2,160 m³/h flow is split between Hc and Hd.
- **Coastal defense cabanons:** A row of small seaside 'cabanon' houses have been constructed like a protective barrier along the coast, with foundations that help guard against flooding.

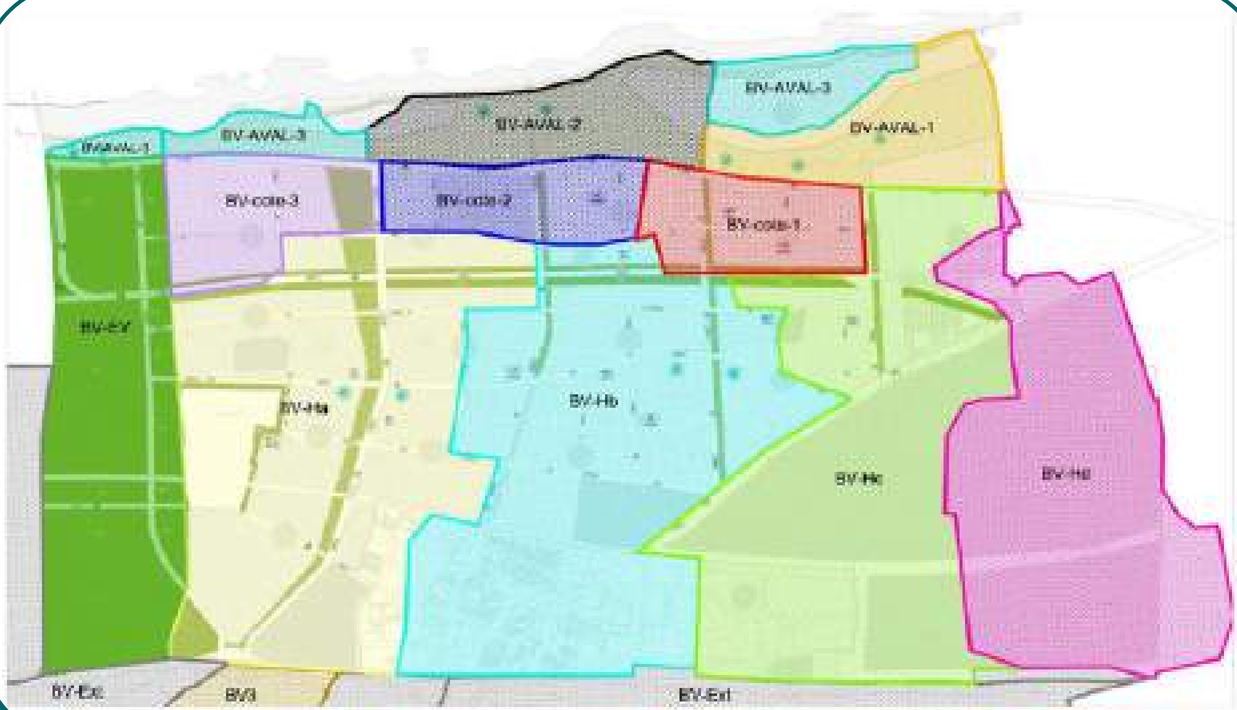

Figure 2. Coverage of stormwater and wastewater collectors in Zenata.
Source: European Investment Bank (2016).

Urban planning and policy timeline

2004
King Mohammed VI launches a national agenda including major reforms and urban development plans.

2006
The CDG Group is awarded the Zenata Eco-City project through a memorandum of understanding signed with the support of King Mohammed VI. The Zenata Development Company (Société d'Aménagement Zenata; SAZ) is established for project oversight.

2008
SAZ releases the Orientation and Development Plan by the Casablanca Urban Agency, developed through broad stakeholder consultation.

2012
Lydec, a public water and electricity utility provider for Greater Casablanca, launches the Casablanca East Anti-Pollution Project to eliminate direct wastewater discharges into the sea.

2015
Zenata Eco-City is awarded the exclusive Eco-City Label by the French High Quality Environmental certification agency as a model project.

2016
A legal framework for developing sewerage networks and wastewater treatment plants as a means to reduce water pollution is enacted.

2018
SAZ partners with UNIDO to promote sustainability in the Zenata industrial park.

2018
Lydec enters into a formal partnership with SAZ to implement smart infrastructure solutions, including potable water distribution and wastewater management.

2021
Nearly all of Zenata, spanning 800 ha, is fully connected to water supply and sanitation networks, completing phase one of drainage systems and potable water infrastructure. This includes sewerage systems and wastewater infrastructure.

Zenata Eco-City master plan.
Source: T+T Design (2012).

Proposed 3D visualisation of Theme Lake Leisure Park.
Source: Arab Urban Development Trust (n.d.).

Climate and environmental impacts

Mitigation:
- Zenata's masterplan promotes low-carbon mobility through dedicated bus and tram corridors, pedestrian-friendly street grids, and cycle paths.
- Bioclimatic architecture minimises reliance on energy-intensive cooling and lighting through strategic orientation, shading, and natural ventilation, reducing operational greenhouse gas (GHG) emissions from buildings.
- Urban vegetation, including 470 ha of green and natural spaces, enhances carbon sequestration, while also improving air quality.

Adaptation a resilience:
- Stormwater retention basins and vegetated corridors reduce surface runoff and urban flooding, while providing a reliable source of non-potable water irrigation and cooling.
- The city's layout channels prevailing Atlantic winds, reducing the urban heat island effect and lowering indoor temperatures.
- Bioclimatic construction increases thermal comfort and reduces exposure to extreme heat, improving resilience for residents in a warming climate.

Other environmental impacts:
- By separating wastewater and stormwater networks, with offshore discharge of treated effluents and on-site stormwater reuse, the project protects marine and groundwater quality
- The use of native plant species in public green spaces and the green infrastructure network enhances local biodiversity and reduces the need for irrigation.
- Urban ecological corridors support species movement and habitat restoration within a densely urbanizing coastal zone.

Financing and funding

Cost structure: The total investment for the Zenata Eco-City is estimated at EUR 800 million, covering infrastructure, housing, services, and public facilities. Development is phased over several decades, with core infrastructure and environmental interventions prioritised in early phases.

Financing sources and instruments: The Zenata Eco-City is primarily financed by the Government of Morocco as the lead investor via CDG's subsidiary, SAZ. This funding is supplemented by international development funds, including the following:
- Government of Morocco as lead investor via CDG's subsidiary, SAZ
- French Development Agency (AFD): EUR 150 million loan
- European Investment Bank (EIB): EUR 150 million loan
- European Union (EU): EUR 4 million grant
- Additional funds are mobilised through land value capture, public-private partnerships, and revenue from real estate development and services.

Cost-benefit analysis: The Zenata Eco-City is expected to generate long-term socio-economic and environmental value through three key avenues:
- **Job creation:** Once completed, 100,000 jobs are expected to be created across logistics, education, health, tourism, commerce, light industry, and public services

- **Environmental returns: The project is expected to lower flood and heat risk, lower GHG emissions, and improve marine water quality**
- **Revenue generation:** Land sales and service concessions are key sources of income for the developer, with revenues reinvested into infrastructure and services.

Stakeholder engagement and social inclusion

- **Multi-level coordination:** A steering panel composed of national and international experts, local authorities, public agencies, and key urban operators guided Zenata's development strategy and its integration within the broader Casablanca region.
- **Community resettlement and inclusion:** The project prioritised the needs of 40,000 residents of informal settlements originally occupying the site. During the preparatory phase, families were temporarily relocated to nearby housing, with dedicated land reserved for permanent reconstruction within the master plan.

Contributors to success

Values:
Zenata embodies a long-term vision rooted in integrated urban planning and water-sensitive design. The city's layout and infrastructure follow bioclimatic principles, while promoting sustainability, livability and water resilience.

Connections:

1. **Physical connection:** Zenata integrates essential urban systems and infrastructure networks — transport, water, waste, energy, and public space — into a cohesive and climate-responsive layout, including through ecological corridors and green-blue infrastructure.
2. **Social connection:** Active collaboration between national and local governments, CDG Group (the state investment fund), international organisations, and local communities has shaped a shared vision. Dedicated stakeholder platforms and resettlement planning have helped ensure inclusion, accountability, and social acceptance.

Investments:
Zenata's phased development has been made possible by strong national government backing and financing from key development finance institutions, including AFD, EIB, and the EU. Public investment in green and smart infrastructure has laid the groundwork for attracting private capital, enhancing long-term investor confidence, and improving alignment with global sustainability standards.

Replicability

With 19 new city developments underway as part of the New Cities initiative, Morocco is among the world's most active countries in constructing entirely new urban areas. Similar trends are seen across Africa and Asia, where countries like Egypt are investing heavily in new towns to accommodate rapid urbanisation. Zenata offers a valuable model for future eco-cities in these contexts — especially those seeking to balance economic growth, environmental resilience, and social inclusion.

Key lessons include the importance of robust public-private governance arrangements, long-term planning frameworks, and integrated urban-water design. Zenata's inclusive resettlement approach — providing affected communities with the means to rebuild homes and access services — demonstrates one method of ensuring social equity during large-scale urban transformation. As Morocco refines its eco-city concept, Zenata's development and operational experience can serve as a benchmark and performance framework for future urban projects across similar geographies.

Overhead view of a 3D model of Zenata Eco-City.
Source: Sparknews (n.d.).

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Chapter 3: Centralised circular water systems and resource recovery

GREATER SANTIAGO, CHILE

Centralised water recycling and reuse

Urban ecosystems restoration and biodiversity

Public-private and multilevel governance models

City overview

Population: 7,400,741 (2024)
Climate: Cool semi-arid climate (Köppen BSk), with Mediterranean patterns (Köppen Csb)
Rainfall: 221.5 mm/year (low)
Water-related risks:

- **Prolonged water stress —** driven by climate change, unsustainable extraction, and weak watershed governance — threatens Santiago's long-term water security. Central Chile has experienced nearly two decades of drought, significantly reducing surface and groundwater availability in the Maipo River basin. By 2070, the basin's water balance is projected to decline by 40%, while demand from urban, agricultural, and industrial sectors continues to rise. Amidst these pressures, aquifers are being depleted faster than they can be replenished, increasing reliance on already stressed river systems.
- **Water contamination** posed serious public health risks prior to the construction of the biofactory wastewater treatment plants. Prior to this initiative, untreated sewage was discharged directly into the Mapocho River, contaminating irrigation water and contributing to outbreaks of enteric diseases.

Case study overview

Initiative name: Biofactories of Greater Santiago (Biofactorías del Gran Santiago)
Location: Greater Santiago, Chile
Period: 2017–Present
Initiative type: Centralised Water Recycling & Reuse
Initiative scale: Site-specific
Main project lead: Aguas Andinas, Degrémont S.A. (now Suez).
Project objective: Convert wastewater treatment plants in Santiago into biofactories that produce clean energy, fertiliser, and reusable water from wastewater and sewer sludge.

Main interventions

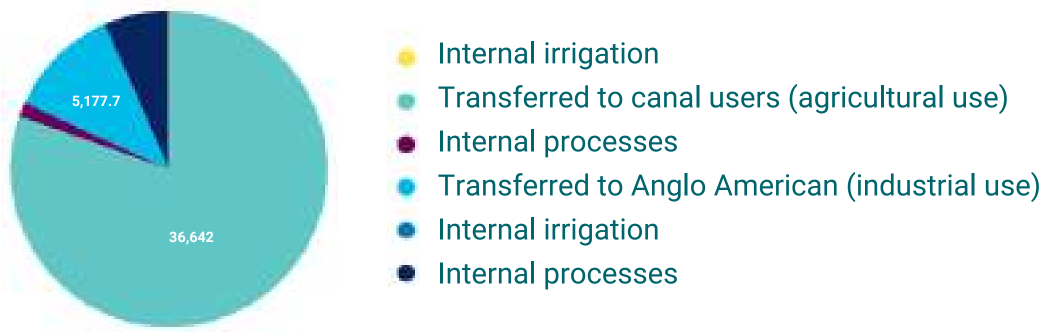
- **Biofactory wastewater treatment plants:** Three major biofactories were built by Aguas Andinas and Suez — La Farfana, Mapocho-Trebal, and El Rutal. Collectively, they treat all of the wastewater produced by Greater Santiago's 8 million residents by applying advanced biological treatment to remove organic matter and solids, producing a combination of reusable water, energy, fertiliser, and construction material.

- **Water reuse:** Wastewater is treated to a high-quality, non-potable standard for reuse in the irrigation of nearby farmlands, particularly during periods of water scarcity and drought.
- **Energy recovery:** Sludge from wastewater is digested to produce biogas, powering cogeneration systems at La Farfana and El Trebal. These plants operate entirely off-grid, with surplus energy fed into the national electricity system.
- **Sludge recovery and biosolids reuse:** Dehydrated and sanitised sludge is turned into biosolids, which are distributed free of charge to farmers for use in agriculture and forestry, replacing chemical fertilisers.
- **Solid waste and sand recovery:** Screenings and sand extracted during treatment are sanitised and reused in construction and road maintenance, further supporting circular material flows and reducing pressure on landfills.

Main outcomes

- **Water reuse and replenishment:** As a result of this initiative, 100% of wastewater produced in the Santiago metropolitan area is treated. In total, 516.7 million m3 of treated water (equal to 90% of Santiago's water consumption) are returned annually to natural water bodies and irrigation canals, supporting agriculture and ecosystem restoration in a water-stressed region. In 2023, 45,600 m3 of treated wastewater was reused, with 36,642 m3 used for agricultural purposes and 5,177.7 m3 transferred to Anglo American for industrial use (Figure 1).
- **Energy generation:** In total, the biofactories generate 57,158 MWh/year of electricity — enough to supply 20,000 households — allowing for energy self-sufficiency. Additionally, the biofactories feed 190,281 MMBTU/year of biomethane into the national gas network, distributed among 35,000 residents.
- **Soil restoration and waste recovery:** Across the three biofactories, 233,581 t of biosolids (representing 80% of the total production) were reused in agricultural soil recovery, with 0% ending up in landfills.
- **Carbon footprint reduction:** Through energy efficiency and circular processes, the initiative has cut Santiago's greenhouse gas emissions by over 5,000 t of CO_2e and saves more than 43,000 GJ of energy annually.

Figure 1: Breakdown of treated water reused in Santiago in 2023 (m3).



Project

Context

In 2005, Santiago treated only 3.6% of its wastewater, with the remainder discharged directly into the Mapocho River, a vital source of potable and irrigation water. This contamination led to frequent outbreaks of enteric diseases, such as typhoid fever, which had affected thousands during the 1980s despite Chile's strong health indicators.

Important regulatory shifts and the privatisation of Santiago's water utility in 1999 — when Aguas Andina assumed responsibility for water supply and sanitation services — enabled significant capital investments in wastewater infrastructure. This marked the beginning of Santiago's transition from a linear wastewater disposal approach to a circular, resource-efficient water system.

Project description

To achieve a 100% rate of wastewater treatment in the Greater Santiago metropolitan area, Aguas Andinas undertook a comprehensive process of infrastructure transformation over 12 years. This entailed eliminating 46 discharge points, which had previously released untreated sewage into the Mapocho River, and developing a 102 km interceptor system to divert wastewater to three modern treatment facilities. Beginning with the launch of the El Trebal wastewater treatment plant in 2000, Aguas Andinas then partnered with Suez under a build-operate-transfer agreement to construct the La Farfana wastewater treatment plant in 2003, at that time the largest in Latin America. The Mapocho plant, opened in 2013, completed the suite of infrastructure needed to treat 100% of Santiago's wastewater.

Building on this achievement, in 2017 Aguas Andinas began converting the La Farfana and Mapocho-Trebal plants into innovative biofactories — circular economy facilities that convert wastewater byproducts into valuable resources such as electricity, biogas, agricultural fertiliser, clean water, and clean air. This pioneering approach gained global recognition in 2018 as a best practice by the UN, and earned Aguas Andinas the 2023 UN Global Climate Action Award for excellence in sustainable water management. Through these efforts, Santiago has become a leading example of sustainable urban water management, successfully transitioning from traditional wastewater disposal to a circular, resource-efficient model.

Total cost

USD 61.2 million (approx. EUR 54.4 million) per wastewater treatment plant upgraded into a biofactory

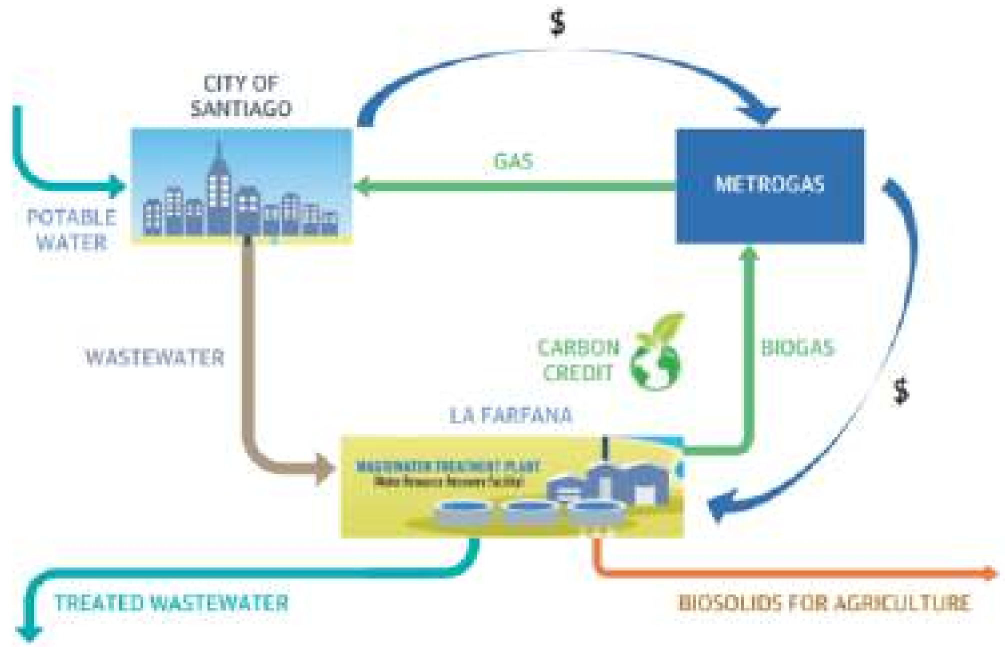


Figure 2. Simplified diagram of the material flows and resources produced by Santiago's biofactories.
Source: World Bank (2019).

Circularity technologies and solutions

- **Wastewater treatment:** Wastewater undergoes a multi-stage treatment process, including screening, grit and grease removal, primary settling, biological treatment, clarification, and chlorination to ensure safe discharge.
- **Closed-loop water reuse:** Treated water is reused for irrigation, supporting urban agriculture and reducing pressure on freshwater supplies, creating a circular urban water system.
- **Biogas and energy production:** Anaerobic digestion of sludge produces biogas, which is purified and transported via pipeline to Metrogas, supplying around 30,000 Santiago households with energy.
- **Biogas cogeneration:** Utilising biogas produced via anaerobic digestion, cogeneration produces both electricity and heat, making treatment plants energy self-sufficient and reducing their fossil fuel use.
- **Biosolid reuse:** Biosolids are dried and repurposed as certified agricultural fertiliser, supporting sustainable farming while minimizing waste for disposal.
- **Material recycling:** Sand and grit recovered from treatment are recycled for construction and landscaping.
- **Emission reduction:** Natural treatment methods and efficient nitrogen removal minimise the use of chemical reagents and energy. This process is registered under the Clean Development Mechanism,[1] generating renewable energy certificates and reducing greenhouse gas emissions.

[1] Under the Clean Development Mechanism, emission-reduction projects in developing countries can earn certified emission reduction credits. These saleable credits can be used by industrialised countries to meet a part of their emission reduction targets under the Kyoto Protocol.

Planning and policy timeline

1984
The Municipal Company of Sanitation Works (EMOS) develops Santiago's first comprehensive sewage master plan. It proposes a new sewer network over 200 km long and a treatment plant to prevent contamination of irrigation channels and meet the sanitation needs of an expanding city.

1986
EMOS publicly sets the target of 100% wastewater treatment coverage by 2024.

1988
The *General Law of Sanitation Services* and the *Tariff Law* reshape the institutional landscape, creating a regulatory framework for setting tariffs and ensuring service quality, while allowing for water utilities to be incorporated.

1992
Santiago's first wastewater treatment plant, Poniente (today, La Farfana) is completed.

1999
Following 1998 regulatory reforms, EMOS is privatised (acquired by Agbar & Suez) and renamed Aguas Andinas. As per their regulatory obligations, private operators must invest in wastewater treatment, ushering in a period of large-scale infrastructure development. At this point, only 3% of Santiago's wastewater is treated.

2003 - 2010
Driven by national and regional planning, over USD 1.3 billion is invested in new treatment plants (namely La Farfana and El Trebal) and infrastructure, aligned with Santiago's broader urban sanitation expansion strategy.

2007 - 2013
Aguas Andinas and the Santiago municipality implement the "Mapocho Urban Limpio" project, with the goal of achieving 100% wastewater treatment coverage for Greater Santiago by 2013. This includes a USD 113 million investment to eliminate 46 points of raw sewage discharge into the Mapocho River.

2017
Aguas Andinas initiates the construction of biofactories, repurposing the La Farfana and Mapocho-Trebal wastewater treatment plants to operate along circular economy principles — generating renewable energy, reusing water, and valorizing biosolids.

2021
The El Rutal wastewater treatment plant is converted into a biofactory for biosolid treatment. Its biosolids are certified as agricultural fertilisers, enabling their commercial use and reducing landfill dependency.

2023
Aguas Andinas launches Biociudad, a water security and resilience program. It integrates urban planning and nature-based solutions to address long-term water stress. Key components include the following:

- Construction of groundwater recharge wells.
- Implementation of rainwater harvesting trenches.
- Redirection of surplus treated water from biofactories for aquifer replenishment.
- Public awareness campaigns on water conservation and behavioral change.

Climate and environmental impacts

Mitigation:

- The Energy Management System and energy efficiency improvements at La Farfana and Mapocho-Trebal reduced energy use by 10% (43,200 GJ), cutting over 5,000 t CO_2e emissions.
- At La Farfana, approximately 12 million m2 of biomethane are generated each year, enough to supply energy to more than 100,000 households.
- Improvements in biogas production at La Farfana have been registered under the Clean Development Mechanism, earning certified emission reduction credits of 26,340 t CO2e/year.
- Biogas from sludge is used to power the plants as well as fed into the city's gas grid, substituting gas from fossil fuels and lowering greenhouse gas emissions

Adaptation and resilience: Reusing treated water in agriculture reduces demand on potable supplies, improving drought resilience and lowering dependency on centralised water systems.

Biodiversity: Studies conducted by Aguas Andinas confirm the return of aquatic life to the Mapocho River, as indicated by the detection of small catfish, Chilean silverside, and mosquito fish.

Agricultural benefits: Organic waste removed from water during purification is utilised in agriculture and soil restoration, either directly as biosolids or after being processed at the El Rutal plant, where it is converted into dry fertiliser. These fertilisers are applied to approximately 30,000 ha of farmland.

Financing and funding

- **Investment costs:** Biofactory upgrades to the La Farfana and Mapocho-Trebel plants (incl. Water reuse, biogas capture and reuse, and biosolid valorisation) required an investment of USD 61.2 million over the period 2018–2020.[2]

- **Operations and maintenance (O&M) costs:**
  - Annual O&M costs are not disclosed, but savings from energy efficiency and biogas generation contribute significantly to operational cost reduction.

- **Finance sources and instruments:**
  - **Tariffs:** Investments are primarily financed by Aguas Andinas through customer tariffs, regulated by the Superintendencia de Servicios Sanitarios.
    - Chile's tariff framework includes a five-year innovation incentive, allowing utilities to retain gains before tariffs are adjusted.
    - Legal provisions explicitly allow the inclusion of capital and O&M costs from waste-to-resource projects in tariff calculations.
    - This structure incentivises innovation and efficiency, encouraging utilities to adopt climate-smart solutions.

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[2] Figures for total investment in the full conversion of the three wastewater treatment plants into biofactories are not available, as upgrades were implemented incrementally over several years.

- **Bonds and debt instruments:** Project financing is secured through a combination of the following instruments:
  - Corporate bonds (issued annually).
  - Green and social bonds (first in Latin America):
    - 2018: USD 68 million over a seven-year term at 1.8% interest
    - 2019: USD 83 million over a 25-year term at 2.0% interest
  - Aguas Andinas' AA+ credit rating (Fitch) and the stable regulatory environment contribute to investor confidence and project bankability.

- **Public-private partnerships and joint ventures:** Aguas Andinas has also entered into different partnerships with the public sector (Figure 3), such as through biogas valorisation with Metrogas in 2002 (agreement signed in 2007). The total project cost of USD 6 million was covered by a 50-50 split investment by Aguas Andinas and Metrogas to provide renewable energy to households.

- **Cost-benefit analysis:**
  - **Energy Management System:**
    - Cost: USD 338,000
    - Benefits: USD 1 million
    - Payback period: 1.7 years
  - **Energy efficiency upgrades (La Farfana and Mapocho-Trebal):**
    - Resulted in a 10% reduction in electricity use
    - Annual savings: over USD 1 million
  - **Additional revenue streams:**
    - Biogas sales
    - Biosolid valorisation (farmers using treated biosolids report 50% savings on fertiliser costs)

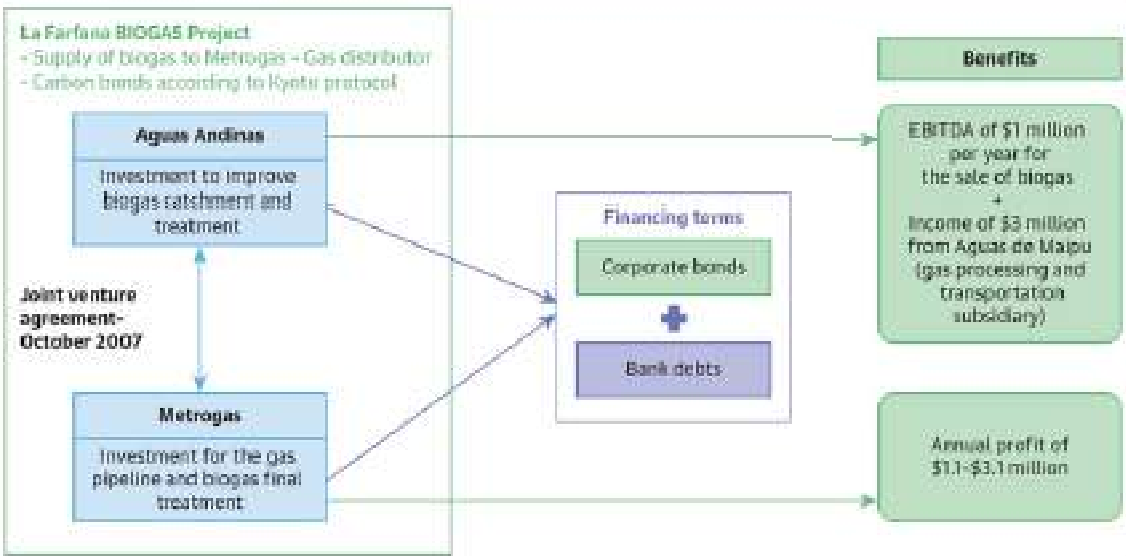

Figure 3. Terms of the 2007 joint venture agreement between Aguas Andinas and Metrogas.
Source: World Bank (2019).

Stakeholder engagement and social inclusion

- **Community participation:** Aguas Andinas engages local communities through dialogue tables near major facilities, involving diverse social organisations to identify priorities and co-design projects. In 2024, 17 community-driven projects were executed, focusing on sports, culture, security, and infrastructure.
- **Direct communication channels:** The “Aló Vecino” hotline allows residents near biofactories to report concerns that are promptly investigated and addressed.
- **Social investment programs:** Since 2008, over 800 community initiatives have been supported through funding programs, with 38 projects funded in 2024. The “Futuro es Femenino” program trained 60 women in sanitary installations in 2024, achieving over 90% retention.
- **Education and awareness:** Approximately 6,700 visitors toured the biofactorías in 2024. Environmental education programs reached over 46,000 students and involved 34 employee volunteers. Additionally, 20 drought-awareness talks engaged 2,000 community members, achieving a 94% satisfaction rate.

Contributors to success

Values: The transformation of wastewater treatment plants into integrated biofactories reflects a shift toward a holistic circular economy model. These facilities recover water, energy, and nutrients, turning wastewater into resources and aligning utility operations with environmental stewardship. This approach values innovation, climate resilience, and the multiple benefits of rethinking wastewater as a source of opportunity.

Connections:

1. **Physical connections:** The expansion of sewer infrastructure enabled wastewater from Greater Santiago to be routed to treatment facilities, achieving 100% wastewater treatment coverage and supporting integrated circular resource flows.
2. **Social connections:** Connections between Aguas Andinas, the local government and other utility companies, such as Metrogas, supported the operational and financial viability of the biofactorías.

Investments: The project was fully funded by a creditworthy private utility, enabling access to capital markets through a mix of green bonds and loans. Chile’s tariff policies incentivised innovation and circular economy practices, while revenue from the sale of recovered resources like biogas and biosolids contributed to financial sustainability.

Replicability

The biofactory approach is replicable in other cities aiming for sustainable wastewater management, particularly where water scarcity, high energy costs, and environmental challenges intersect. Its success relies on supportive regulatory frameworks, innovative financing mechanisms (such as green bonds), and local markets for byproducts like biogas and biosolids. The Suez Group, owner of Aguas Andinas, has also implemented the biofactory model in wastewater treatment plants in Spain, demonstrating its adaptability and applicability to cities of varying sizes, infrastructure maturity, and climatic conditions — making it suitable for both developed and developing contexts.

In Morocco, wastewater treatment and reuse are critical priorities due to limited water resources and growing urban populations. The country generates approximately 1.4 billion m3 of wastewater annually, yet only around 18% is currently treated. With over 400 wastewater treatment plants nationwide and ambitious targets set by the Ministry of Equipment and Water — such as utilizing 100 million m3 of treated wastewater by 2027 under the National Program for Drinking Water and Irrigation Water Supply 2020–2027 — there is significant potential to adopt the biofactory approach. Cities like Marrakech and Kenitra, which already operate large wastewater treatment plants with biogas generation and reuse, could adopt other elements of biofactories, including water recycling and biosolid production. Generalizing such practices across Moroccan cities, building integrated biofactories which can use turn wastewater into clean energy, water to irrigate golf courts and green spaces, and agricultural fertilisers, could contribute to the country's broader goal for sustainable and resilient water management.

Aerial view of the La Farfana biofactory
Source: ohstgo.cl (n.d.)

The view over the La Farfana biofactory.
Source: Planetary Health Alliance (2025).

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BioFactory Santiago
Source: felicidadpublica.cl

Chapter 3: Centralised circular water systems and resource recovery

SURAT, GUJARAT, INDIA

- Centralised water recycling and reuse
- Urban ecosystems restoration and biodiversity
- Public-private and multilevel governance models

City overview

Population: 8,602,322 (est. 2025)
Climate: Tropical Savanna climate (Köppen Aw), with hot humid summers, monsoon season, and dry winters
Rainfall: 1,240 mm/year (high)
Water-related risks:

- **High vulnerability to flooding** from the Tapi River, worsened by monsoon rains and dam releases, with major events recorded in 1968, 1994, 1998, and 2006. In 2006, 95% of the city was submerged, resulting in about 120 fatalities.
- **Frequent water supply disruption** due to dependence on the Ukai Dam, with seasonal low water levels and contamination from untreated industrial and domestic wastewater affecting purification.

Case study overview

Initiative name: Surat Industrial Water Supply Initiative
Location: Surat, Gujarat, India
Period: 2014 - present
Initiative type: Centralised Water Recycling & Reuse
Initiative scale: City-wide
Main project lead: Surat Municipal Corporation (SMC)
Project objective: Recycle wastewater through advanced tertiary treatment for reuse in industrial clusters, reducing pressure on freshwater sources and enabling sustainable industrial development in Surat.

Main interventions

- **Tertiary treatment plants (TTPs):** Advanced wastewater recycling technologies (sand filtration, ultra filtration, reverse osmosis, and activated carbon) integrated into existing sewage treatment plants (STPs), supplying treated water for industrial reuse.
- **Dedicated network for industrial reuse:** Closed-loop, non-potable water grid, fully separated from the city's potable water system, supplying treated wastewater to the Pandesara and Sachin industrial clusters.
- **Water handling infrastructure:** Dedicated water tanks, pumps, and blending tanks ensure consistent pressure and supply, regardless of demand and production.
- **Backwash wastewater management:** Sumps to collect and recycle filter wash water from treatment processes, enhancing resource efficiency and circularity.

Main outcomes

- **Recycled wastewater distributed for industrial reuse:** As of 2024, total of 330 million L per day (MLD) of treated wastewater (20% of Surat's total wastewater treatment output) is recycled and reused, including 115 MLD of tertiary-treated water specifically supplied to textile industries in the Pandesara and Sachin industrial areas. By January 2024, 173 billion L of wastewater had been recycled and supplied to industries.
- **Revenue generation:** By January 2024, the project generated over INR 4.96 billion (EUR 49.5 million) in revenue from industrial-grade water sales, demonstrating a financially sustainable model for wastewater reuse.
- **Reduced industrial freshwater consumption:** Affordable recycled water supply significantly decreased freshwater use by the textile and dyeing industries, contributing to water conservation and reducing ecological pressure on the Tapi River.
- **Infrastructure–industry co-location:** The strategic co-location of new tertiary treatment plants and industrial clusters enables efficient distribution of recycled water for industrial reuse.
- **Expansion and scalability:** Continuous expansion of water treatment and recycling capacity reflects the project's ability to meet growing industrial water demand.

Total cost

- INR 3.14 billion (EUR 31.3 million) (as of 2024)

Project

Context

Surat, a rapidly growing industrial city in Gujarat, faces significant water-related challenges driven by rapid urbanisation, industrial expansion, and flood risks exacerbated by global climate change. The city's economy is heavily reliant on water-intensive sectors such as textile manufacturing and diamond polishing, which place substantial pressure on freshwater resources. Its dependence on the Tapi River and the Ukai Dam has become increasingly unsustainable, while the discharge of untreated or partially treated sewage has further degraded local water bodies. To address these challenges, the Surat Municipal Corporation (SMC) launched the Industrial Water Supply Initiative to scale up the reuse of treated wastewater, reduce environmental pressure, and conserve limited freshwater supplies.

Project description

Launched in 2014 by the SMC, the Industrial Water Supply Initiative addresses the city's rising industrial water demand through the reuse of treated wastewater. The first Tertiary Treatment Plant (TTP), Bamroli Phase I, was operationalised at the existing Bamroli sewage treatment plant (STP) in 2014, followed by Bamroli Phase II and Dindoli in 2020. Implemented through public-private partnerships (PPPs), the TTPs were developed under an engineering, procurement, and construction (EPC) contract comprising a 10-year operations and maintenance (O&M) agreement between SMC and Enviro Control Associates, with the Singapore-based Hyflux serving as a technology partner.

Using ultrafiltration and reverse osmosis to treat wastewater (Figure 1), these three TTPs produce 115 million L per day (MLD) of high-quality, industrial-grade recycled water, which is distributed via pipelines to industrial zones like Pandesara and Sachin, primarily for use in water-intensive sectors like the textile industry (Table 1). The TTPs are complemented by secondary treatment facilities (Figure 2) that supply recycled water for a wider range of non-potable uses, including agriculture, construction, gardening and landscaping, lake regeneration, and ecological restoration (Table 2). Revenues generated from recycled water sales for these non-potable uses ensure the project's financial sustainability.

The TTPs are complemented by secondary treatment facilities that supply recycled water for a wider range of non-potable uses including agriculture, construction, gardening and landscaping, lake regeneration, and ecological restoration.

By integrating advanced water recycling with broader non-potable reuse, Surat offers a scalable model of a circular and resilient water management system that reduces pressure on freshwater sources such as the Tapi River and the Ukai Dam, while generating revenue, improving environmental quality, and supporting climate adaptation. It offers a replicable strategy for other rapidly urbanizing cities facing the dual challenges of water scarcity and industrial growth.

Circularity and resilience solutions

TTPs and water reuse: Surat operates three TTPs equipped with ultrafiltration, active carbon filters, and reverse osmosis systems to treat wastewater and produce 115 MLD of high-quality recycled water for industrial use, advancing the city's goal of zero liquid discharge.

On-site reuse: Treated water is reused for cleaning and operations at wastewater facilities, reducing overall water demand.

Resilience to drought: Continuous supply of recycled water supports industrial operations during dry periods, enhancing economic resilience and stability.

Scaling wastewater reuse city-wide: Surat aims to achieve 100% reuse of treated wastewater by 2035, expanding infrastructure and reuse applications across sectors (Table 3).

Table 1: Existing STPs and integrated TTPs in Surat (2024)

STP	Capacity (MLD)	TTP capacity (MLD)	Year established	Technology	Recipient industries
Anjana	122.0				
Bhesan	200.0				
Bhatar	277.0				
Karanj	211.0				
Singanpore	255.0				
Bamroli-Vadod	215.0	**Phase I** Input: 57.0 Net output: 40.0	2014	Ultra Filtration + Reverse Osmosis	Pandesara Industrial Estate
		Phase II Input: 50.0 Net output: 35.0	2020	Ultra Filtration + Reverse Osmosis	Sachin Textile Industries
Asarma	37.5				
Khajod	55.0				
Variav-Kosad	134.0				
Dindoli	167.0	Input: 57.0 Net output: 40.0	2020	Ultra Filtration + Reverse Osmosis	Pandesara Industrial Estate
Gavier	53.0				
Total	1726.5	Input: 164.0 Net output: 115.0			
GHB Gem & Jewellery Park*	5.0	5.0	2014	Sequencing Batch Reactor + Ultra Filtration	Gujarat Hira Bourse

***Note**: GHB Gem & Jewellery Park is a privately operated facility with its own tertiary treatment plant and is not affiliated with the Surat Municipal Corporation (SMC).

Table 2: Recipient industries of recycled wastewater from tertiary and secondary treatment facilities in Surat (2024)

Recipient sector	Treated wastewater reused (MLD)
Tertiary treatment	
Textile industry clusters	115.0
Secondary treatment	
Other industrial reuse	112.0
Reuse in treatment process at STPs	49.0
Agriculture	28.0
Construction (incl. a metropolitan rail project and biodiversity park)	20.0
Gardening and landscaping	17.0
Landfill closure and ecological park	5.0
Lake regeneration	2.0
Waste-to-compose facility	1.0
Biodiversity park	0.5
Dream City Project	0.5
Total	**330.0**

Table 3: Planned TTPs in Surat (2024)

STP	Additional Capacity (MLD)	TTP output capacity (MLD)	Recipient industries
Varachha	150.0	100.0	Palsana Enviro Protection Pvt. Ltd.
Dindoli	100.0	75.0	Gujarat Eco-Textile Park & New Palsana Industrial Coop. Soc. Ltd.
Total	250.0	175.0	

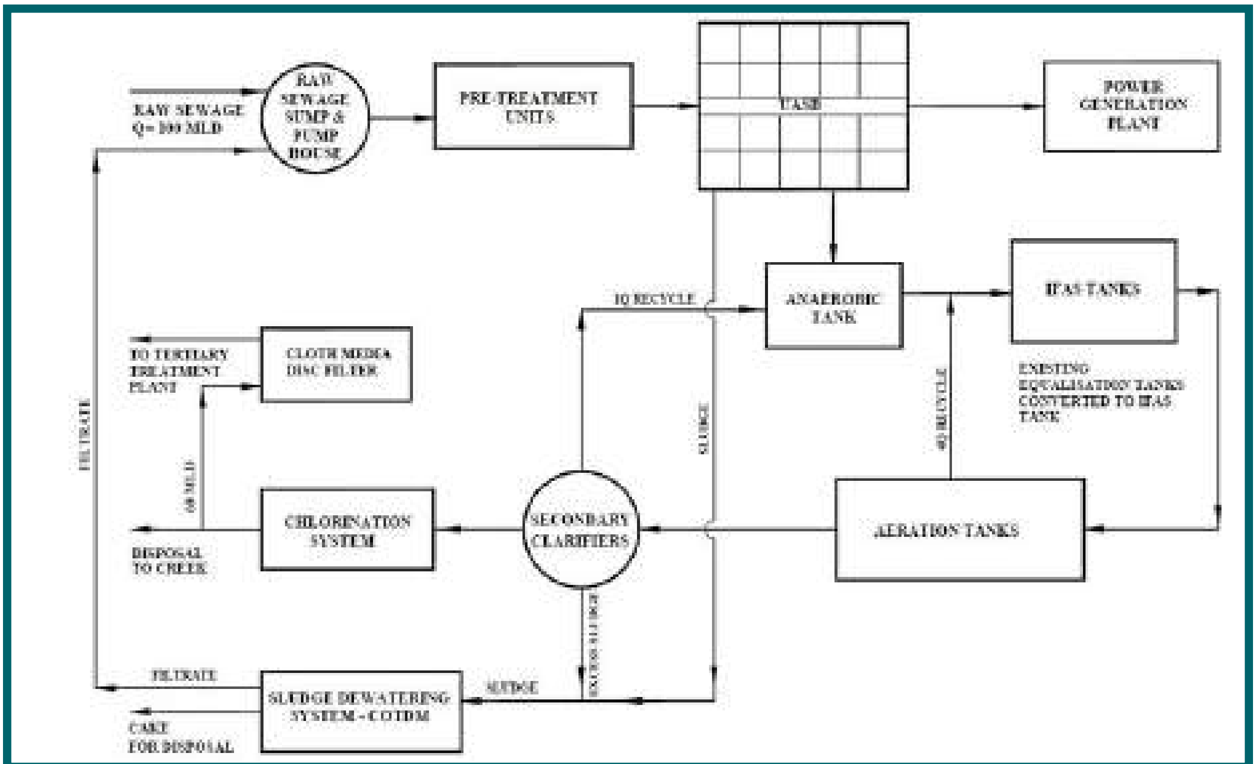

Figure 1: Flow diagram of the treatment process at the Bamroli Phase II STP
Source: Vashi et al. (2019).

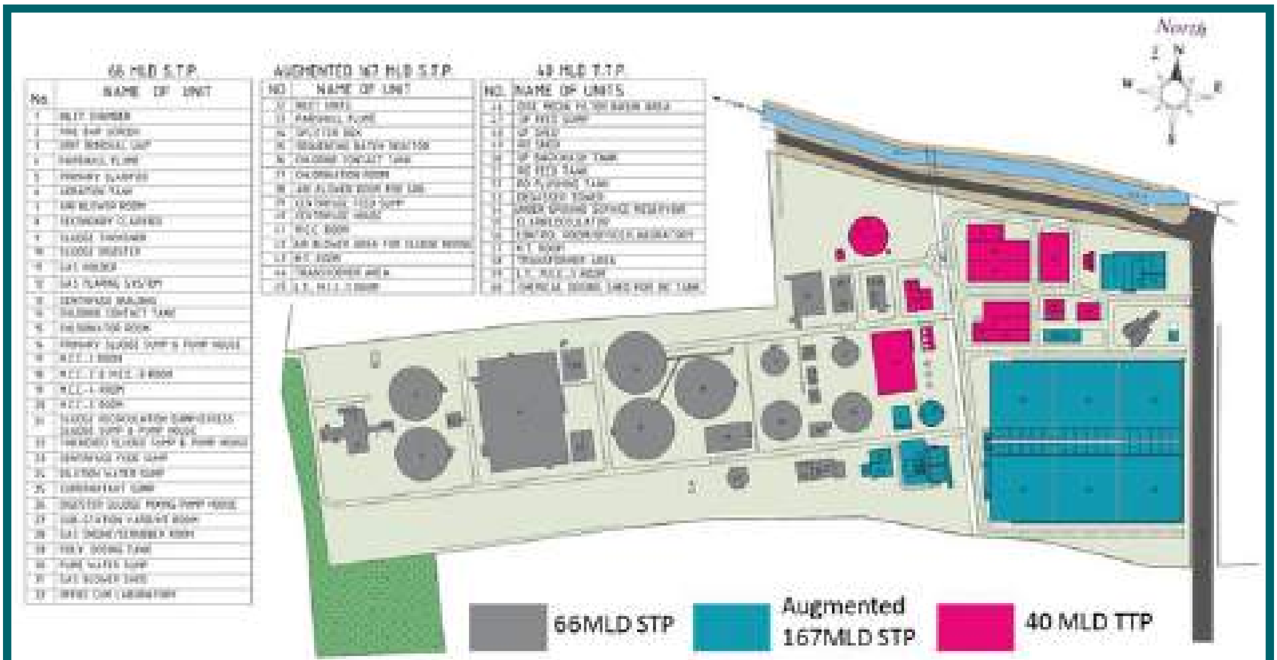

Figure 2. Layout of a TTP integrated with an existing STP
Source: Smart Cities and Academia towards Action and Research (2023).

Urban planning and policy timeline

2011
Initial plans for the Bamroli Phase I TTP are developed with support from the Asian Development Bank and Pandesara Industrial Estate.

2014
The Bamroli Phase I TTP is operationalised, supplying 40 MLD of recycled water to Pandesara industrial zone.

2015
The Government of India launches the Smart City Mission to promote sustainable urban development through resource efficiency, circular economy practices, and improved infrastructure. In Surat, the Smart City Mission supports and co-finances the construction of the Dindoli TTP.

2017
SMC adopts the *Surat Resilience Strategy*, highlighting water reuse as a priority response to water scarcity and groundwater stress.

2018
The Government of Gujarat adopts the *Policy for Reuse of Treated Waste Water*, providing a regulatory framework for municipal corporations to scale up water reuse. The policy sets targets of 70% reuse by 2030 and 100% by 2035, and mandates the use of recycled water by industrial estates within urban areas.

2019
SMC adopts the *Treated Wastewater Reuse Action Plan*, aligning with Gujarat State policy. This plan identifies industrial users (Sachin and Pandesara) and includes a pricing structure, infrastructure plans, and an implementation roadmap.

2020
The Bamroli Phase II and Dindoli TTPs become operational, adding 75 MLD in recycled water capacity.

Wastewater treatment plant in Varachha
Source: Surat Municipal Corporation (2024)

Intake well of a TTP within Surat's Industrial Water Supply Initiative.
Source: Surat Municipal Corporation

2024
SMC signs memoranda of understanding with three additional industrial estates to supply recycled water from upcoming TTPs in Dindoli and Varachha.

Climate and environmental impacts

Mitigation:

- Domestic and industrial wastewater accounts for 2.34% of India's greenhouse gas (GHG) emissions, primarily due to methane and nitrous oxide released via organic matter decomposition.
- Centralised wastewater treatment and reuse can significantly reduce these GHG emissions. A study conducted in Shaanxi, China (Liu et al., 2024), found that industrial wastewater recycling reduced GHG emissions by 10.46% per ton of treated water compared to conventional supply.

Adaptation and resilience:

- The Surat Industrial Water Supply Initiative provides a stable and drought-resilient water source for industrial users, ensuring operational continuity during periods of municipal water scarcity.
- Dedicated reuse pipelines linking TTPS and industrial clusters ease pressure on potable water systems, strengthening the city's capacity to manage climate-related water stress.
- The long-term conservation of freshwater sources, especially groundwater, is critical for both human wellbeing and ecological systems.

Biodiversity:

- The three TTPs divert treated wastewater from local water bodies, such as creeks and the Tapi River, reducing pollutant loads entering natural ecosystems.
- High treatment standards (biological oxygen demand < 5 mg/L and total dissolved solids < 500 mg/L) minimise nutrient and chemical loads, supporting healthier aquatic environments.
- The TTPs replace informal or poorly treated industrial water sources, reducing risks of soil and water contamination.

Financing and funding

- **Cost structure:**
    - **Investment:** As of 2025, the total capital cost for the construction of the three operational TTPs was INR 3.14 billion (approx. EUR 31.3 million; Table 4).
    - **O&M:** Annual O&M costs are estimated at INR 403.3 million (EUR 4.2 million). These are fully covered by revenue from user charges paid by industrial water consumers (Table 4).

Table 4: Capital and O&M costs of the three TTPs established by the Surat Industrial Water Supply Initiative ca. 2022.

TTP	Capacity (MLD)	Year est.	Capital cost	O&M cost per year	Total revenue (ca. Oct. 2022)
Bamroli - Phase I	35.0	2014	INR 851 million (EUR 8.5 mi)	INR 186.4 million (EUR 1.9 mi)	INR 2.5 billion(EUR 24.8 mi)
Bamroli - Phase II	40.0	2020	INR 1.04 billion(EUR 10.4 mi)	INR 126.6 million (EUR 1.3 mi)	INR 658.1 million (EUR 6.6 mi)
Dindoli	40.0	2020	INR 1.25 billion(EUR 12.5 mi)	INR 90.3 million(EUR 0.9 mi)	INR 564.5 million (EUR 5.6 mi)

- **Finance sources and instruments:** Although the TTPs are operated through PPPs, with private partners handling EPC and O&M, their capital costs were primarily funded by public resources, with varying financing structures:

    - **Bamroli Phase I:** Fully financed by the Government of Gujarat under the Swarnim Jayanti Mukhya Mantri Shaheri Vikas Yojana scheme.
    - **Dindoli:** Funded by the Government of India via the Smart Cities Mission (59.3%) and Surat Municipal Corporation (40.7%).
    - **Bamroli Phase II:** Financed mostly by a Government of Gujarat grant (93%) and partially by the private sector (7%).

- **PPP model:** Two separate contracts were awarded to the private partner, Enviro Control Associates: one for EPC and one for O&M.
    - Revenues from the sale of recycled water are collected by SMC and used to pay the O&M contractor.
    - The original tender for Bamroli Phase I, developed with the Asian Development Bank, was structured as a design-build-finance-operate- maintain PPP model. However, it was later abandoned when SMC recognised the potential to generate direct revenue from water sales.

- **User-pays model:** Capital and O&M costs are recovered through user fees for industrial-grade recycled water. This fee was initially set at INR 18.20 (EUR 0.18) per 1,000 L in 2014 and rose to INR 36.22 (EUR 0.36) in 2024 — still approximately 30% cheaper than that of freshwater. As of January 2024, the three TTPs have generated a total revenue of INR 4.96 billion (EUR 49.5 million).

- **Cost-benefit analysis:**
    - **Economic benefits:**
        - The TTPs have an average payback period of 6 years, with ongoing revenues covering O&M and enabling future expansion.
        - Industrial users benefit from lower water costs and reliable supply, supporting long-term, sustainable economic growth.
    - **Environmental benefits:** Reduced pressure on freshwater and groundwater sources maintain ecological integrity and ensure long-term environmental sustainability.
    - **Social and operational benefits:** Reliable, high-quality water supply for industries improve resilience to drought-related disruptions.

Stakeholder engagement and social inclusion

- **Partnership with the industrial sector:** SMC developed the wastewater reuse project in close coordination with local industries, securing long-term bulk reuse agreements. By offering a reliable, affordable and high-quality source of water for industrial use, this partnership ensured financial stability for the project and fostered private-sector buy-in for sustainable water use.
- **Institutional capacity and professional oversight:** A dedicated project management consultant was appointed for project preparation, design, and implementation oversight. This professionalised project delivery while strengthening internal capacity through structured collaboration with municipal staff.
- **Knowledge exchange and recognition:** Surat's water reuse model has served as a benchmark at national and international levels. It has motivated visits from diverse stakeholders, including a Parliamentary Consultative Committee, and has been showcased at Smart Cities forums and the Stockholm World Water Week (2021). These platforms helped share learnings

and build public confidence in the project's innovation and safety.

- **Awareness and community outreach:** Through SMC's broader information, education, and communication efforts — such as school visits, workshops, and public seminars — citisens have been engaged with water conservation and reuse. These efforts contribute to broader social acceptance of using high-quality recycled wastewater for industry.

Contributors to success

Values: The project placed an emphasis on circular, sustainable water management as key to long-term economic growth and resource resilience. This reflected a commitment to balancing industrial development with environmental protection through innovative reuse practices.

Connections:

1. Physical connections: Dedicated reuse pipelines linking TTPs to industrial users create an efficient, reliable water supply network.
2. Social connections: Strong collaboration among municipal, state, and national authorities, as well as industries, consultants, and knowledge-sharing platforms, fostered trust, shared learning, and public confidence.

Investments: The circular wastewater reuse system generates consistent revenue through bulk reuse agreements with industrial users, forming a financially sustainable and replicable business model. Investments in professional project management and capacity-building ensure quality and reduce risks.

Replicability

Since its launch, the Surat Industrial Water Supply Initiative has become a benchmark for circular and resilient urban water management. By supplying approximately 115 MLD of treated wastewater for industrial use, Surat reduces its reliance on freshwater sources and mitigates environmental pollution. Its success is built on advanced treatment technologies, dedicated, non-potable reuse networks, a well-structured PPP model, strong governance, and financial sustainability through user charges. The PPP model generates large revenues for the municipality while keeping recycled water prices significantly below those of freshwater, making it both cost-effective and attractive to industry. Together, these elements position Surat as a model for cities seeking to balance economic growth with ecological sustainability and climate resilience.

In Morocco, cities with large, water-intensive textile and chemical industries — such as Casablanca and neighboring Mohammedia and Settat — face rising water stress and pollution from industrial effluent. Surat's approach offers a proven blueprint to transform treated wastewater into a reliable, economically viable resource for industry. Key features like TTPs, non-potable distribution networks, integrated governance frameworks and the user-pays model can be tailored to the Moroccan context. Additionally, Surat's emphasis on capacity-building, cost recovery, and cross-sector collaboration also offers valuable lessons for fostering local expertise and social acceptance. Adopting such an approach could accelerate Morocco's transition to a circular, climate-resilient water system in its industrial centers.

Surat sewage reuse model.
Source: Surat Municipal Corporation (2024).

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Chapter 3: Centralised circular water systems and resource recovery

SAFI, MOROCCO

Centralised water recycling and reuse

Desalination and non-conventional supply

City overview

Population: 346,100 (2025)
Climate: Hot semi-arid climate (Köppen BSh)
Rainfall: 325.12 mm/year (low)
Water-related risks:

- **Water stress:** Morocco faces severe water stress. The Safi region is situated in one of the most affected catchment areas, where water demand exceeds 80% of available freshwater resources.
- **Water contamination:** The Bay of Safi is increasingly exposed to pollution due to expanding industrial activities along the coastal zone.
- **Drought:** Climate change has intensified the frequency and severity of droughts in the region, putting additional pressure on water resources and threatening agricultural productivity.

Case study overview

Project name: Safi Circular Water Economy Model
Location: Safi, Morocco
Period: 2022–Present
Initiative type: Desalination of seawater and industrial reuse of wastewater
Project scale: City-wide
Main project lead: OCP Green Water (a subsidiary of Office Chérifien des Phosphates; OCP)
Project objective: To address the increasing demand for water for non-potable, industrial use and potable purposes in Safi, thereby addressing persistent water shortages exacerbated by extended droughts in the Oum Er Rbia basin.

Main interventions

- **Urban wastewater treatment:** Advanced wastewater treatment includes screening, biological and tertiary processes and sludge digestion.
- **Cogeneration system:** Heat energy generated from sulfuric acid production during wastewater treatment is recovered and converted into electricity through cogeneration technologies, enhancing the treatment plant's energy efficiency.
- **Desalination plant:** A multi-stage process — including pre-treatment, filtration, and reverse osmosis — is used to produce high-quality freshwater.
- **Liquid effluent management:** Brine and cleaning effluents are diluted with cooling seawater before being safely discharged into the sea.
- **Utilisation of non-conventional water resources:** In line with its water neutrality strategy, OCP

Green Water is committed to using only non-conventional water sources for its industrial activities.

Main outcomes

- **Increased water supply:** At full future capacity, the first desalination plant will supply 23 million m³/year to OCP's industrial operations, while the second will supply 20 million m³/year of drinking water to the residents of the Safi region.
- **Freshwater conservation:** Using seawater for desalination reduces the need to extract fresh groundwater or surface water.
- **Energy efficiency:** A cogeneration system supplies 40% of the electricity required to operate the desalination plant, enhancing energy efficiency.
- **Minimised marine impact:** The desalination plant generates 3,600 m³/h of liquid waste, which is treated and diluted to just 2% of the total discharge volume. This waste treatment process ensures minimal impact on the marine environment.
- **Urban wastewater management:** STEP Safi has the capacity to treat 11,7Mm³/year.
- **High effluent quality standards:** Compliance with effluent quality standards at BOD5 ≤ 10 mg/l, COD ≤ 50 mg/l, TSS ≤ 10mg/l.
- **Job creation:** The project generates 250 direct and 500 indirect jobs during construction, and 50 direct and 200 indirect jobs during operation.

Project cost

MAD 600 million (approx. EUR 60 million)

Project

Context

Morocco is under severe and worsening water stress, with annual water availability at just 790 m³ per capita. The city of Safi (Figure 1), a major hub for sardine fishing and phosphate exports, lies within a particularly water-stressed catchment along the Atlantic coast, where demand exceeds 80% of the available freshwater supply.

As a key regional economic actor, OCP Green Water (a subsidiary of Office Chérifien des Phosphates; OCP) has committed to supplying non-conventional water resources to support both its industrial operations and nearby communities through the Safi Circular Water Economy Model. Beyond industrial and municipal supply, the project also aims to help mitigate the broader impacts of water shortages, which threaten public health, food security, economic stability, and may contribute to social tensions and internal migration.

Figure 1. Map of Safi.
Source: www.safi-ville.com

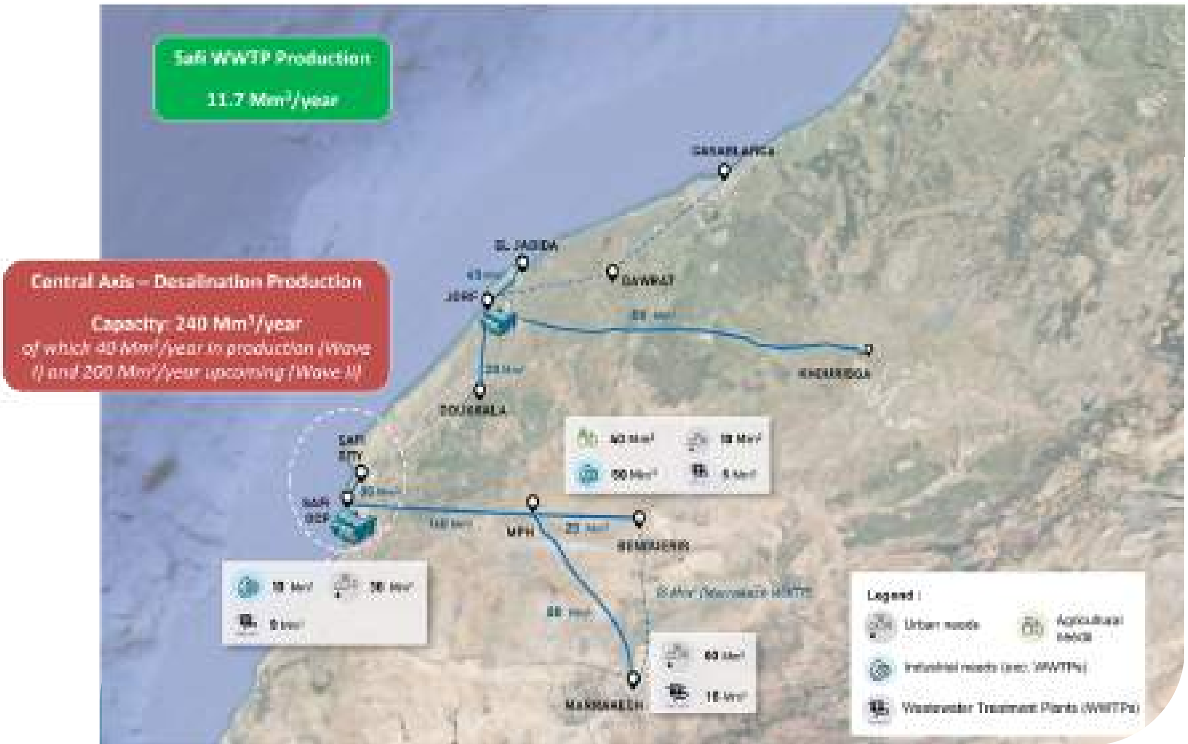


Figure 2. Desalination and Wastewater Treatment Infrastructure in Safi (OCP Central Axis)
Source: OCP Green Water (2025, August) "Modèle de Circularité d'Eau: Semaine Mondial de l'Eau" (PowerPoint Presentation)

Project description

The Safi Circular Water Economy Model involves the construction of two seawater desalination facilities, along with associated infrastructure such as pre-treatment station, reservoirs and pipelines, to supply water for industrial purposes as well as drinking water to the city of Safi (Figure 2). This approach significantly reduces OCP's broader reliance on freshwater for its water-intensive industrial processes. Given the region's growing vulnerability to drought, this transition supports more sustainable water management and greater water security for the city's residents.

The first desalination plant, located on a 2ha site, is designed to provide water for OCP's industrial operations, most prominently the production of acid used in fertiliser manufacturing. It features 14 reverse osmosis modules with an annual production capacity of 22 million m3. The second plant, situated on a 2.5 ha site, is dedicated to supplying drinking water to the city of Safi. To facilitate water delivery, an underground distribution network of pipes will transport drinking water from the desalination facilities to storage tanks. This includes a 92 km pipeline that connects the city's desalination plant to the Azib Drai reservoir for effective water distribution. Wastewater produced during operation is treated and reused for industrial purposes.

In addition, wastewater, which originates from the urban municipal sewer system of the city of Safi, is treated and then directed to a pre-treatment station and pumping infrastructure operated by Autonomous Intermunicipal Water and Electricity Distribution Authority of Safi (RADEES), before being conveyed to the STEP purification facility for industrial use.

Circularity and resilience solutions

- **Urban wastewater treatment:** Advanced processes include screening, primary treatment, activated sludge (biological), tertiary treatment (sand filtration and chlorination), and sludge valorisation (anaerobic digestion, thermal hydrolysis, and cogeneration).
- **Desalination plants:** The two plants employ advanced technology, primarily reverse osmosis, to transform seawater into safe, potable water. This process includes several filtration stages, ending with specialised membranes that effectively remove salts and minerals. At the second plant, the purified water is then remineralised to meet international drinking water standards before being supplied to local communities.
- Cogeneration system: Steam generated by the sulfuric acid units form part of an exothermic industrial process is used to produce electricity.
- **Liquid effluent management:** During operation, the desalination process produces wastewater, primarily brine, which is subsequently diluted by mixing it with seawater used for cooling various units in the Safi industrial complex. As a result, only 2% of the total volume of wastewater is released into the sea through existing outflow pipes. Additionally, industrial effluents from cleaning the reverse osmosis filters and membranes are neutralised before being combined with the cooling seawater.

Planning and policy timeline

2020
As part of its 2020–2050 National Water Plan, the Moroccan government launches the 2020–2027 National Program for Potable Water Supply and Irrigation (PNAEPI).

2023
The Government of Morocco and OCP Green Water sign a memorandum of understanding, with the latter agreeing to supply drinking water to the cities of Safi, El Jadida, and nearby areas through seawater desalination.

2023
The plants begin operations, supplying 10 million m³/year of potable water to Safi under PNAEPI guidelines.

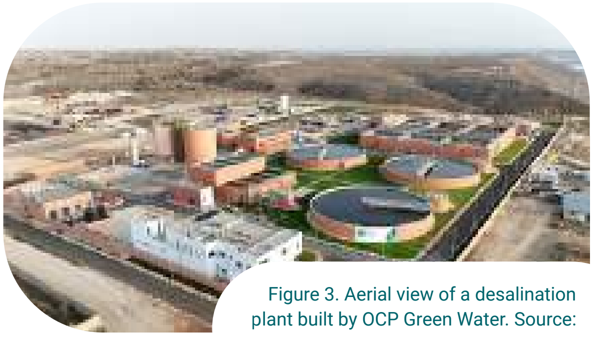
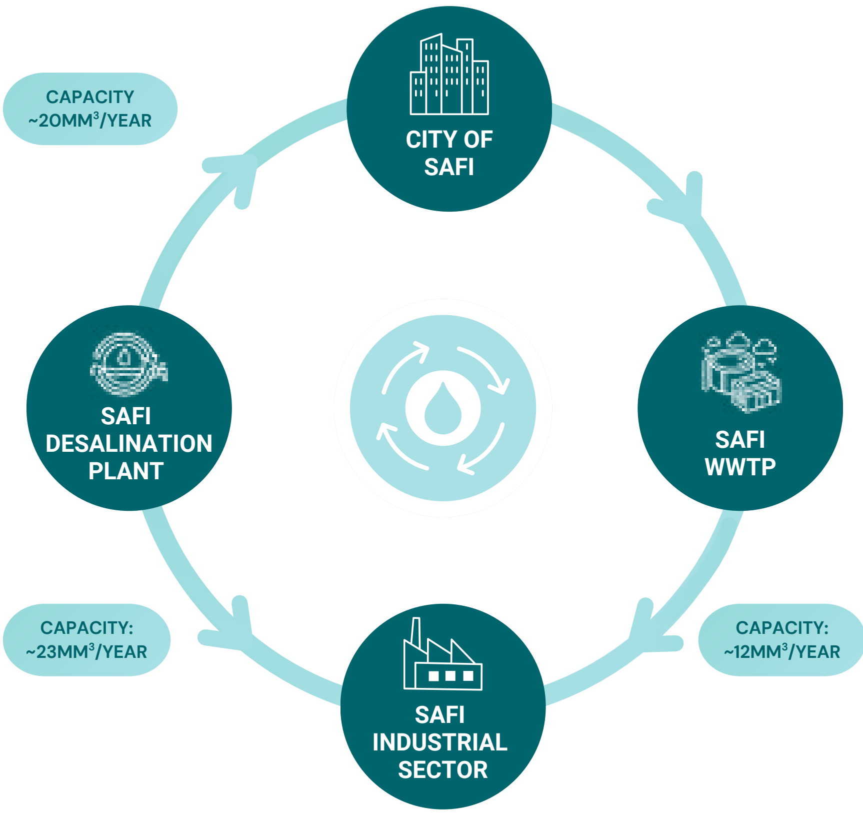


Figure 3. Aerial view of a desalination plant built by OCP Green Water. Source: OCP Green Water.

2024 - 2026
The supply of desalinated water to Safi is expected to reach 15 million m3/year, with plans to further increase this to 30 million m3/year starting in 2026.

Figure 4 : Water circularity model in the city of Safi
Source: OCP Green Water



Climate and environmental impacts

Mitigation: Approximately 40% of the desalination plant's electricity demand is supplied by a cogeneration system, helping to lower the project's carbon footprint and greenhouse gas emissions.

Resilience: By utilizing non-conventional water sources through desalination to supply industrial activities and drinking water, the project helps to preserve Safi's freshwater resources and improve its resilience in the face of future climate change and drought scenarios.

Financing and funding

Cost structure:

- **CAPEX:** >40 Billions of MAD (approx. 3,791,184,000 EUR) for four plants. If considering only Safi, it is roughly 1 Billions MAD (947,796,000 EUR).

Financing sources & instruments: The European Bank for Reconstruction and Development provided a loan of EUR 200 million for four plants, including two in Safi.

Cost-benefit analysis: The project has had a positive socio-economic impact by boosting engineering services, trade, and industry in the region. It will support local businesses and generate new jobs, with 250 direct and 500 indirect jobs during construction, and 50 direct and 200 indirect jobs during operation. In addition, it reduces the costs related to the purchase and treatment of fresh water, creating value through the circular economy.

Stakeholder engagement and social inclusion

Stakeholder engagement: The project has created a network of national and local government and external stakeholders involved in project development and implementation, in which OCP GreenWater manages water supply facilities upstream of the Marrakech-Safi Regional Multiservice Company (Société Régionale Multiservices Marrakech-Safi; SRM-MS). SRM-MS, in turn, oversees downstream facilities of the meter, including water distribution and customer relations. OCP has also contracted JESA, in a joint venture between Woley Parsons and OCP, as the engineering, procurement, construction, and maintenance contractor for the seawater desalination project.

Social inclusion: OCP Green Water has organised public information meetings, workshops, discussion groups, home visits, material provision, and educational programs for vulnerable groups in the region, including women, the elderly, children,people with disabilities, and ethnic communities. This has helped to secure their involvement in consultation processes, ensure that their concerns are considered in project planning and implementation, and provide assistance where needed.

Contributors to success

Values:

1. The project recognises the value of Safi's freshwater resources in a changing climate, and commits to utilizing non-conventional water sources, namely desalinated seawater, as a viable alternative to decrease demand on this precious resource. In doing so, the project meets 100% of OCP's industrial water demand, while also providing secure drinking and irrigation water to approximately 1.5 million people in the region, helping to prevent health issues linked to unsafe water consumption.

Connections:

1. **Physical connections:**
   - The project consists of two plants producing 50 million m3 of freshwater annually. This water is transported via pipelines, pumping stations, and storage tanks to industrial areas and cities such as Marrakech, improving water availability in dry regions.
   - By minimizing dependence on highly stressed freshwater resources, the project contributes to maintaining the integrity of the region's interconnected hydrological systems.
   - The project regularly tracks the population trends and health of marine flora and fauna, ensuring that its activities do not undermine ecological resilience.

2. **Social connections:**
   - **Stakeholder networks:** Thanks to strong connections with local authorities, national government, and various groups within civil society during the planning and implementation phase, the project could respond to the needs of the community and adapt to national targets and policy requirements,
   - **Environmental integrity:** By applying various methods such as assessment of biodiversity, conducting marine ecology monitoring program, bi-monthly marine water quality monitor and complaint mechanism, the project prevented harmful impacts of plant construction and operation on the environment, biodiversity, water resources, and residents.
   - **Employment and business opportunities:** Project construction and operations have generated employment opportunities in engineering services and specialised laboratories, boosting local trade, industry, and small businesses.

Investments: The substantial capital investment into the project, financed by OCP Green Water and supported by national and multilateral partners, was critical to its success. At a national level, Morocco has committed MAD 383 billion (EUR 37.6 billion) over 30 years to modernise its water infrastructure for domestic and agricultural purposes, as part of a comprehensive plan spanning the period 2020–2050, ensuring the continued operation and maintenance of the plant.

Replicability

The Safi desalination plants represent an important step forward in Morocco's fight against water scarcity. Leveraging advanced technology and sustainable methods, the project not only meets current water demands, but also lays the foundation for a more secure water future. As climate change increasingly threatens conventional water sources, initiatives like this will play a key role in supporting the long-term resilience and sustainability of regions facing similar environmental challenges.

The desalination project is a key component of Morocco's 2020–2027 PNAEPI, a strategic effort to ensure water security nationwide. Between 2020 and 2027, the program will invest MAD 115 billion (approx. EUR 11 billion) to build nine new desalination plants, delivering a combined annual capacity of 202 million m3 of water for southern cities like Agadir, Safi, and Laâyoune. Beyond these projects, Morocco plans to develop eight additional desalination plants with a total capacity exceeding 1.1 billion m3/year. The Safi project can act as an example for other future projects with similar initial conditions.

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