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Digital Transformation For Growing Water Utilities

Bringing Safe and Reliable Water To All





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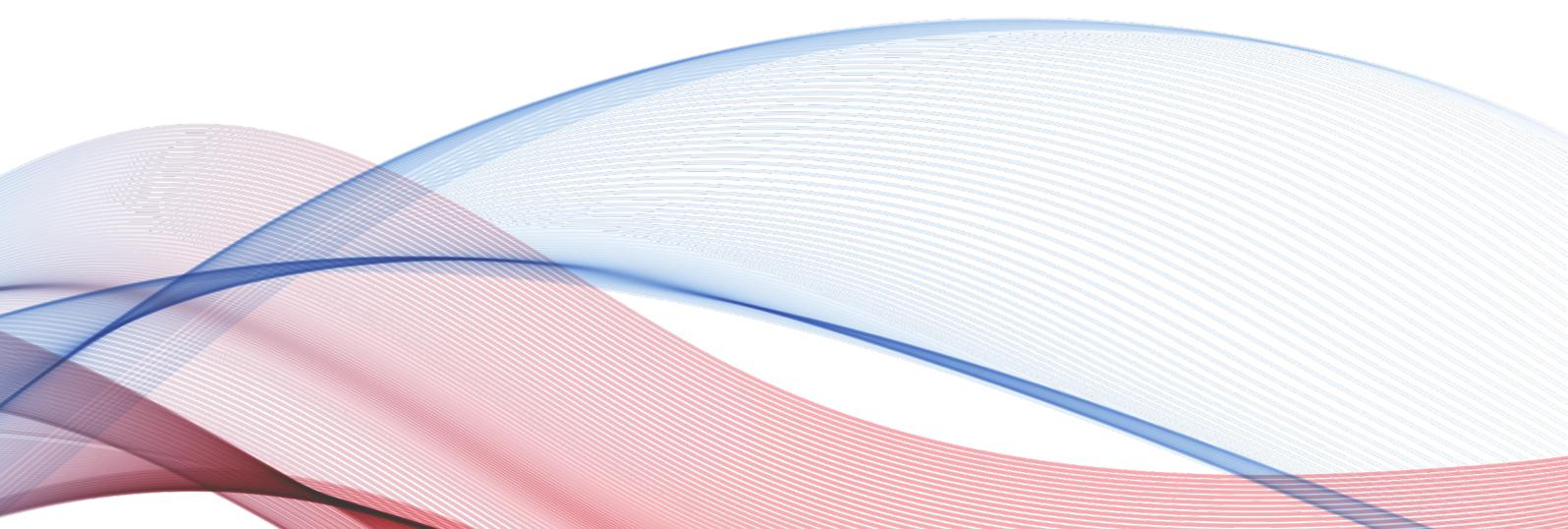


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Foreword

Water has shaped civilizations, driven economic growth, and sustained human life for millennia. Yet today, we stand at a critical juncture, facing large looming problems such as depleting water sources, increasing demand for water in urban areas, and mounting environmental challenges. Many water utilities globally, especially in emerging nations, are struggling with aging infrastructure, inefficient operations, and financial constraints that limit service expansion. When every drop counts, business-as-usual is no longer viable.

Digital transformation offers a way forward – empowering utilities with end-to-end visibility across water production, distribution, and consumption, while optimizing efficiency throughout the value chain. But technology alone is not enough. True transformation requires a clear strategy, strong leadership, and collaboration to ensure effective and sustainable digital implementation.

This report, co-authored by the Japan International Cooperation Agency (JICA) and Boston Consulting Group (BCG), builds on JICA's¹ decades of leadership in the water utilities space and its collaboration with BCG to offer a structured guide for the digitalization of water utilities, by focusing on the following questions:

- **Understanding the Need for Digitalization:** What are major KPIs and pain points of utilities addressable by digital? What is digital transformation for water utilities? How to assess digital maturity? What does an ideal end-state digital architecture look like? What initiatives should utilities pursue at each level of digital maturity? What role can AI play in optimizing utility operations?
- **Value from Digitalization:** Why should utilities undertake digital transformation? How can digital transformation of utilities help make progress towards socioeconomic goals?
- **Successful Execution of Digitalization:** What factors influence the success of digitalization? How does digital transformation play out in real world? How should utilities prioritize and phase their digital initiatives? What is the investment requirement for digitalization?

The challenges facing water utilities are complex, but not insurmountable. Collaborative effort from utilities, governments, and development partners can help build a more efficient, financially resilient, and future-ready water sector. The moment to act is now. We invite all stakeholders to join forces to enable utilities worldwide to harness the power of digitalization to secure sustainable water access for future generations.

¹Japan has been the top donor in the international cooperation in the water and sanitation sector from 2007 to 2017. To read more about JICA's activities in this space, please read the [cluster strategy document](#)

Executive Summary

Today, **we stand at a critical turning point in global water management.** By 2030, global water demand will exceed supply by 40%², a crisis fueled by climate change, rapid urbanization, inefficient water management, and unsustainable consumption. Yet, even as billions face growing water scarcity, water utilities – responsible for sourcing, treating, and delivering water – lose over 126 billion cubic meters of water annually, with the average utility losing almost one-third of its treated water due to leakages or unbilled consumption³. Aging infrastructure, underinvestment, and inefficient management limit the ability of utilities to meet rising demand, ensure financial viability, and expand access to safe water.

The World Bank⁴ projects that a typical water utility loses USD 21.38 million annually due to inefficiencies, while the International Water Association⁵ estimates the financial losses from Non-Revenue Water globally at USD 39 billion per annum.

Now, imagine a world where every drop of water is accounted for – where utilities trace water movement in real time, from its source to the tap, ensuring minimal wastage. AI-powered analytics detect leaks before they happen, smart meters optimize consumption, and predictive systems ensure water is treated and distributed with maximum efficiency and minimal energy use. No longer constrained by manual processes and fragmented data, utilities can respond dynamically to demand, reduce losses, and provide sustainable, high-quality service to all communities. **This is no longer a distant vision but a realizable future through the digital transformation of water utilities.** When combined with ongoing infrastructural, operational, and strategic improvements, digitalization empowers utilities to move from reactive crisis management to proactive, data-driven operations.

This report, developed by the Japan International Cooperation Agency (JICA) and Boston Consulting Group (BCG), serves as a guide for utilities, governments, and development partners navigating the digital transformation of water utilities. This report draws on JICA's decades of global leadership in supporting water utilities, built through effective financial and technical assistance. Between 2011 and 2020, **JICA's efforts provided safe water to over 30 million people and trained 100,000 professionals globally**⁶. Recognizing the potential of digital transformation to create growing water utilities, JICA has partnered with BCG to support digitalization of utilities in several emerging nations. Building on this experience, this report highlights the necessity of digitalization, the potential value it can generate, and the best practices for effective implementation.

²Source: United Nations. Retrieved from: [Half the World to Face Severe Water Stress by 2030 unless Water Use is "Decoupled" from Economic Growth, Says International Resource Panel](#). ³Source: International Water Association. Retrieved from: [Quantifying the global non-revenue water problem | Water Supply | IWA Publishing](#) ⁴Source: World Bank; retrieved from: [Why investment in water is crucial to tackling the climate crisis | World Economic Forum](#) ⁵Source: International Water Association. Retrieved from: [Quantifying the global non-revenue water problem | Water Supply | IWA Publishing](#) ⁶Source: JICA

Understanding the Need for Digitalization of Water Utilities

Water utilities, regardless of their stage of development, face a **complex set of challenges** across their value chain – from managing high Non-Revenue Water (NRW) losses and maintaining asset health to expanding service coverage, improving customer satisfaction, and ensuring financial sustainability. Many utilities, however, find themselves trapped in a **vicious cycle** of low service quality, declining customer trust, and insufficient revenue generation, which erodes their creditworthiness and prevents them from securing the investments needed to enhance service levels. Breaking this cycle requires a fundamental shift in how utilities operate. By leveraging digital technologies, utilities can evolve into **Growing Water Utilities**, which can generate stable revenue streams, reducing reliance on subsidies, and unlocking funding through retained earnings, bond issuances, and direct borrowing.

However, Digital Transformation entails more than technology adoption. It is a strategic, end-to-end process – one that integrates advanced digital tools across the value chain, strengthens governance frameworks, and builds digital capabilities within the workforce. When paired with ongoing investments in infrastructure, operational efficiency, and long-term planning, digitalization becomes a powerful multiplier, accelerating utilities' ability to deliver high-quality, financially sustainable, and scalable water services.

6 Layers of the Digital Tech Architecture for Water Utilities

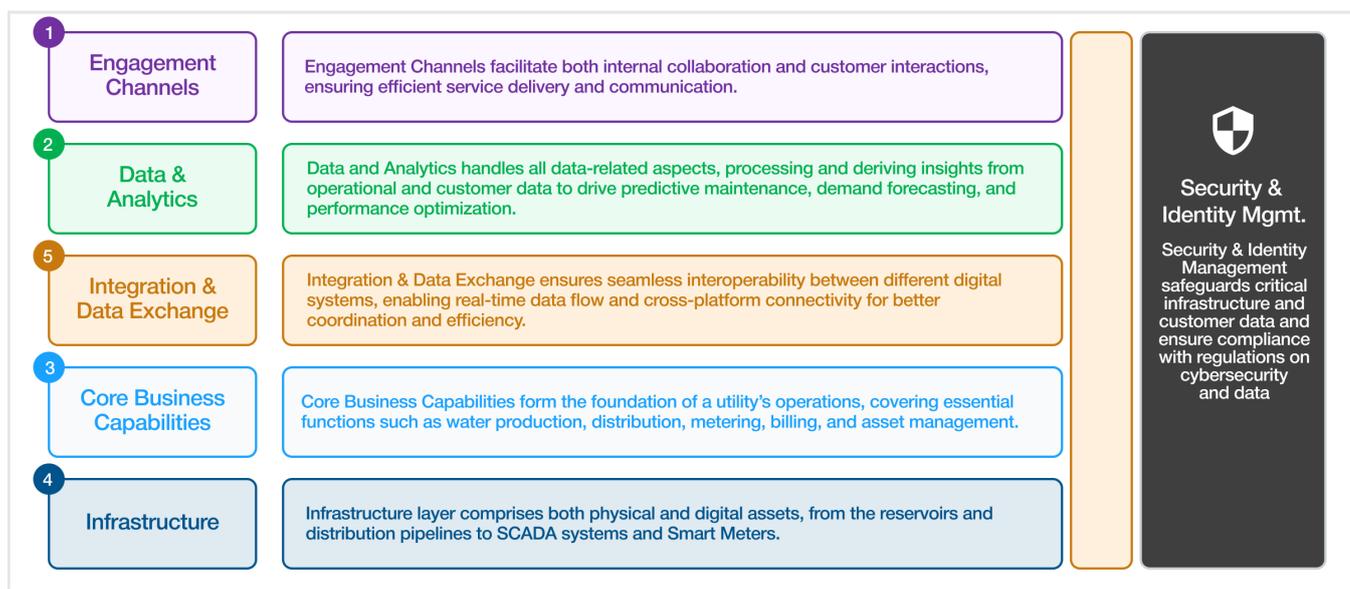


Figure 1: 6 Layers of Digital Technology Architecture for Water Utilities

For any utility pursuing digital transformation, it is crucial to **understand the digital technology architecture**, which consists of six major layers. Each of these layers comprises several key components and systems, which this report explores in depth, outlining the **ideal end-state architecture** for water utilities.

Utilities must conduct an **evaluation of their current digital maturity level** at the onset of their transformation journey. Digital maturity level is determined by a utility’s capabilities across six key parameters: **Digital Strategy, Digital Engagement, Digital Business Processes, Data Analytics and AI, Digital Infrastructure and Security, and Digital Organization, Talent, and Ways of Working**. Based on these parameters, utilities can be categorized into five levels of digital maturity:

Digital Maturity Framework: Competencies for 5 Levels of Maturity

	Legacy	Basic Digitalization	Intermediate Digitalization	Digitalization	Advanced Digitalization
Digital Strategy	No defined strategy in place	Siloed digitalization initiatives but no overarching strategy or org-wide focus on digitalization	Strategy in place with well-defined roadmap & value case (including KPIs) Execution underway	Strategy in place with proven track record of execution and value realization	Strategy continuously refined with learnings from execution, value realized & industry trends
Digital Engagement	No digital channels for customer or employee engagement	Introduction of assisted comms channels (e.g., call center) and SMS / email based comms	Self-service capabilities through web portals and mobile apps e.g. customer portal	One-stop digital engagement e.g. end-to-end customer lifecycle / relationship management	Holistic digital engagement with customers, employees, and external stakeholders e.g., weather services
Digital Business Processes	Paper-based core business processes (e.g., production, distribution, and metering); limited to no automation	Siloed digitalization across core business processes (via SCADA, Asset mgmt. etc.); however, significant manual work persists	Increasing digitalization of core processes (e.g., billing NRW) & support functions through ERP & other industry standard systems	Majority of business processes are optimized & digitalized through advanced systems (e.g., VFD, PLC, Hydraulic Modelling) leveraging AI	State-of-the-art digital platforms , continuous improvement and feedback cycles in place
Data Analytics & AI	Manual and non-standardized data recording in silos. Basic financial and operational reports, generated manually	Foundational data platform (e.g., RDBMS, ODS) used; data quality issues persist. Select financial and operational reporting automated	Centralized data platform with improved data quality for BI - Analytics (e.g., NRW, Mgmt. Dashboard)	Data-driven decisions leveraging AI/ML models, high-quality data across core business processes (e.g., demand forecasting, early warning systems)	Leverage ecosystem data (e.g., weather, satellite) to drive more accurate, holistic AI/ML predictions; seamless interoperability with data exchange
Digital Infra and Security	Siloed IT infra with limited security controls	Basic digital infra (e.g., IT device mgmt.) with basic security controls and reactive approach to incidence response	Standard digital infra (e.g., IoT sensors) with well defined security controls, & regular audits	Optimized digital infra (e.g., Ultrasonic flow meter, Smart Meter) leveraging AI based capacity planning & predictive security controls	Autonomous, self-healing digital infra with threat intelligence for seamless and secure integration with ecosystem partners
Digital Organization, Talent, Ways of Working	No dedicated full-time IT / digital team ; only basic infra / operational maintenance capabilities	Small IT/ digital team (<5 people) to run basic digitalization initiatives and O&M	Medium sized IT team with select digital skills; few digital programs driven with program level governance	Strong IT / Digital teams with strategic sourcing and capability to execute digital programs and innovation agenda	State of the art digital capabilities built (e.g., Innovation Lab, AI CoE); large programs successfully done

Figure 2: Digital Maturity Framework for Water Utilities

Depending on their current level of digital maturity, utilities must prioritize different initiatives and capabilities to advance their digital transformation journey. Utilities at lower maturity levels should focus on establishing foundational digital infrastructure, such as SCADA systems and basic automation, while more advanced utilities should leverage AI, advanced analytics, and interoperable digital ecosystems to enhance efficiency, optimization, and seamless integration. For instance, a South Asian utility, highlighted in **Case Study 4A**, embarked on a structured digital transformation journey at an early stage of digital maturity (Level 2).

To accelerate its progress, it prioritized the development of an NRW Monitoring Tool, a Management Dashboard, and a Meter Reading App, among other digital solutions.

As utilities progress toward Advanced Digitalization, AI must be strategically embedded across the value chain to transform predictive maintenance, demand forecasting, operational decision-making, and customer service, enabling them to fully unlock the power of their digital capabilities. AI-based solutions are also creating new opportunities for startups. In **Case Study 2A**, we cover a Japanese startup that is leveraging satellite Data Analytics and GIS asset data to provide AI-driven leakage risk assessment and management solutions, helping utilities enhance efficiency and reduce water losses. **Solutions such as AI-based predictive water quality** monitoring, which leverage IoT sensors and AI models to enable real-time data analysis for early issue detection, are also gaining traction globally among advanced utilities.

Early adopters of AI have been able to **reduce energy consumption by over 25%** and **reduce OPEX in asset maintenance by over 30%**, showing the promise of AI to drive value creation for Water Utilities⁷.

Value from Digitalization – What Digital can Bring for Utilities and Communities

Organizations in the Power, Utilities and Renewables sector with strong Digital and AI capabilities reported a **1.3x EBIT⁸ uplift** compared to industry peers, directly attributed to their digital and AI advancements⁹.

In today's digital age, organizations are rapidly adopting **technology to drive efficiency and value creation**—and water utilities are no exception. Digital Adoption has enabled utilities to improve operations and achieve measurable efficiency gains across their value chain, which comprises **Assets and Investments, Production, Distribution, Collections and Customer Support, and Management/Support Functions**.

From **reducing procurement spending by up to 1%** with the help of AI to analyze contract documents to **decreasing NRW % by 25%** points through digitization of billing, smart metering, and GIS tagging, water utilities have experienced significant benefits from digitalization globally¹⁰.

⁷JICA and BCG research. ⁸EBIT (Earnings Before Interest and Taxes) is a financial metric that measures a company's operating profitability by calculating revenue minus operating expenses, excluding interest and tax expenses. ⁹BCG research. ¹⁰JICA and BCG research.

While digitalizing water utilities enhances efficiency and financial sustainability of utilities, it also drives progress toward several **UN Sustainable Development Goals (SDGs)**:

- 1. Good Health and Wellbeing (SDG 3):** Digital technologies enable real-time water quality monitoring, leak detection, and predictive maintenance, ensuring early intervention before contamination reaches communities.
- 2. Clean Water and Sanitation (SDG 6):** Leak detection, demand forecasting, and smart metering help utilities reduce water losses and optimize treatment processes, improving water availability, conservation, and distribution efficiency.
- 3. Gender Equality (SDG 5):** Predictive maintenance and automated water scheduling prevent supply disruptions, reducing the burden on women and girls for collecting water, allowing for greater participation in education and the workforce.
- 4. Zero Hunger (SDG 2):** Digitalization of water utilities ensures a safe water supply for drinking, food preparation, and sanitation, preventing waterborne diseases that cause malnutrition. By reducing contamination risks, it supports better nutrition, especially for vulnerable populations.
- 5. Sustainable Cities and Communities (SDG 11):** Drought forecasting, satellite monitoring, and smart distribution systems enhance water resource management, reduce sudden water shortages, and strengthen climate resilience in growing cities.
- 6. Climate Action (SDG 13):** Energy optimization through digitalization can reduce water utilities' carbon footprint by minimizing energy waste, while predictive analytics help mitigate the risks of climate-induced droughts and floods.
- 7. Decent Work and Economic Growth (SDG 8):** Digital transformation creates new job opportunities in AI, IoT, and infrastructure management, while improving service efficiency, reducing operational costs, and driving economic productivity.

Furthermore, digitalization significantly enhances data availability and reliability in the water sector, creating opportunities for private players to develop innovative solutions that benefit communities. For instance, smart home technologies now integrate with residential water meters, providing personalized conservation insights, automating water-saving actions, and optimizing appliance usage. These solutions can help optimize consumption and promote more efficient and sustainable water use.

Successful Execution of Digitalization – How Utilities Can Navigate the Path to Digital Transformation

Digital transformation is a **strategic journey** that demands structured and **cohesive planning and operationalization** to achieve success and obtain the desired end results. The exhibit below outlines the **six key steps** in operationalizing digital transformation:

Steps to Operationalizing Digital Transformation of Water Utilities

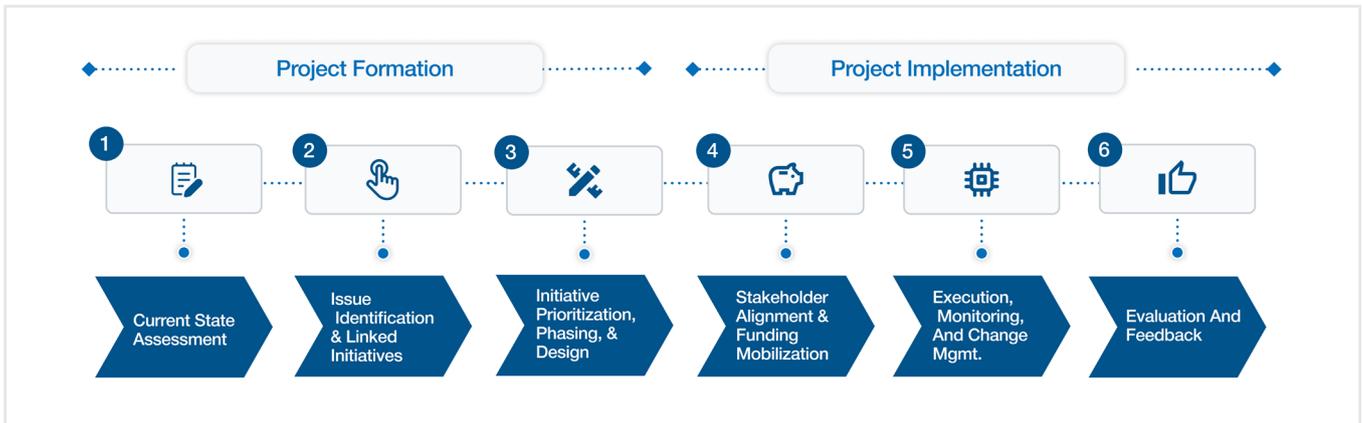


Figure 3: Steps to Operationalizing Digital Transformation of Water Utilities

Across industries, the success rate of all digital transformation projects is roughly 30%¹¹, meaning that majority of digital transformation projects **fall short of their goals**, leading to wasted resources, lost time, and missed opportunities to unlock the full potential of digitalization. However, there are **6 key success factors that help differentiate the winning digital transformations** from the ones that fall short:

6 Key Success Factors for Digital Transformation

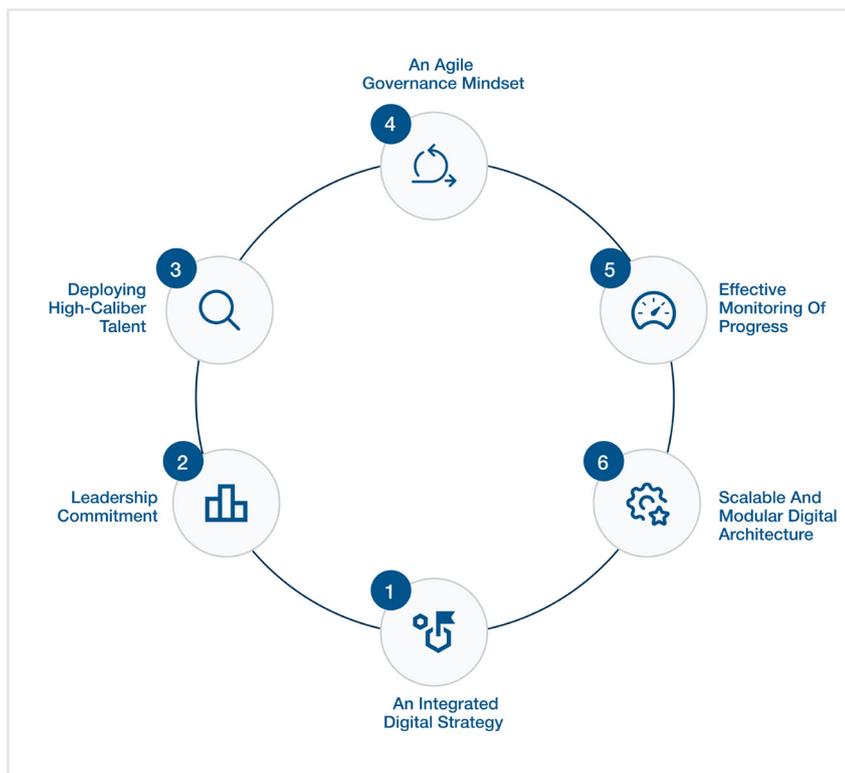


Figure 4: 6 Key Success Factors for Digital Transformation

¹¹BCG research

One critical component of the Digital Strategy is the initiative roadmap, which includes the initiatives to be implemented and their implementation timelines. The **Digital Initiative Prioritization and Phasing Framework** provides a structured approach for utilities to assess, prioritize, and phase digital initiatives. The process **involves three key steps**:

- (1) Developing a long list of initiatives through benchmarking and stakeholder consultation,
- (2) Prioritizing initiatives based on their Impact and Ease of Implementation (EoI), and
- (3) Phasing initiatives into three categories – **Quick Wins**, **Major Projects** (including Foundational Initiatives), and **Incremental Initiatives**.

Digital Initiative Prioritizations and Phasing Framework

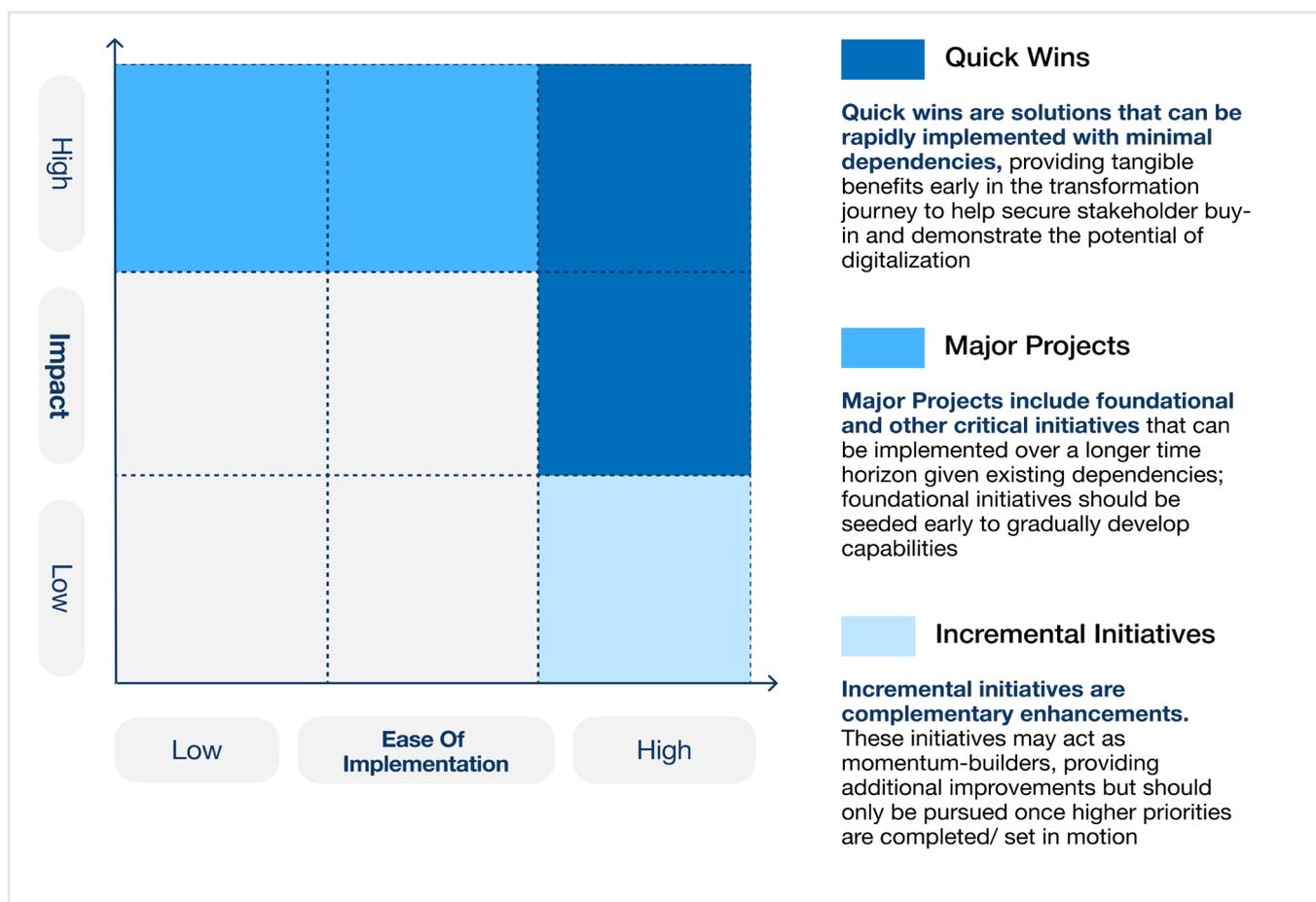


Figure 5: Digital Initiative Phasing and Prioritization Framework

The cost of digital transformation for utilities can vary widely, often reaching millions of dollars, depending on utility size, regional context, existing IT maturity, and prioritized initiatives. For instance, a utility in an emerging nation, starting its digital transformation journey at Level 1-2 maturity, serving approximately 100,000 connections, and with access to affordable IT manpower, would **need to invest ~USD 30-40 million (in one time Capex) phased over 5-10 years for a comprehensive digital transformation**.

Annual Opex in the first year for digitalization initiatives can range from USD 100,000 to USD 2 million, depending on the complexity of the initiatives, level of enhancements, ongoing maintenance, support, and cloud subscription costs. More advanced and integrated solutions (e.g., Municipal level control center) typically require higher operational expenditures to ensure system reliability, scalability, and continuous optimization. To manage these investments, utilities frequently collaborate with development partners who provide financial support, technical expertise, and strategic guidance.

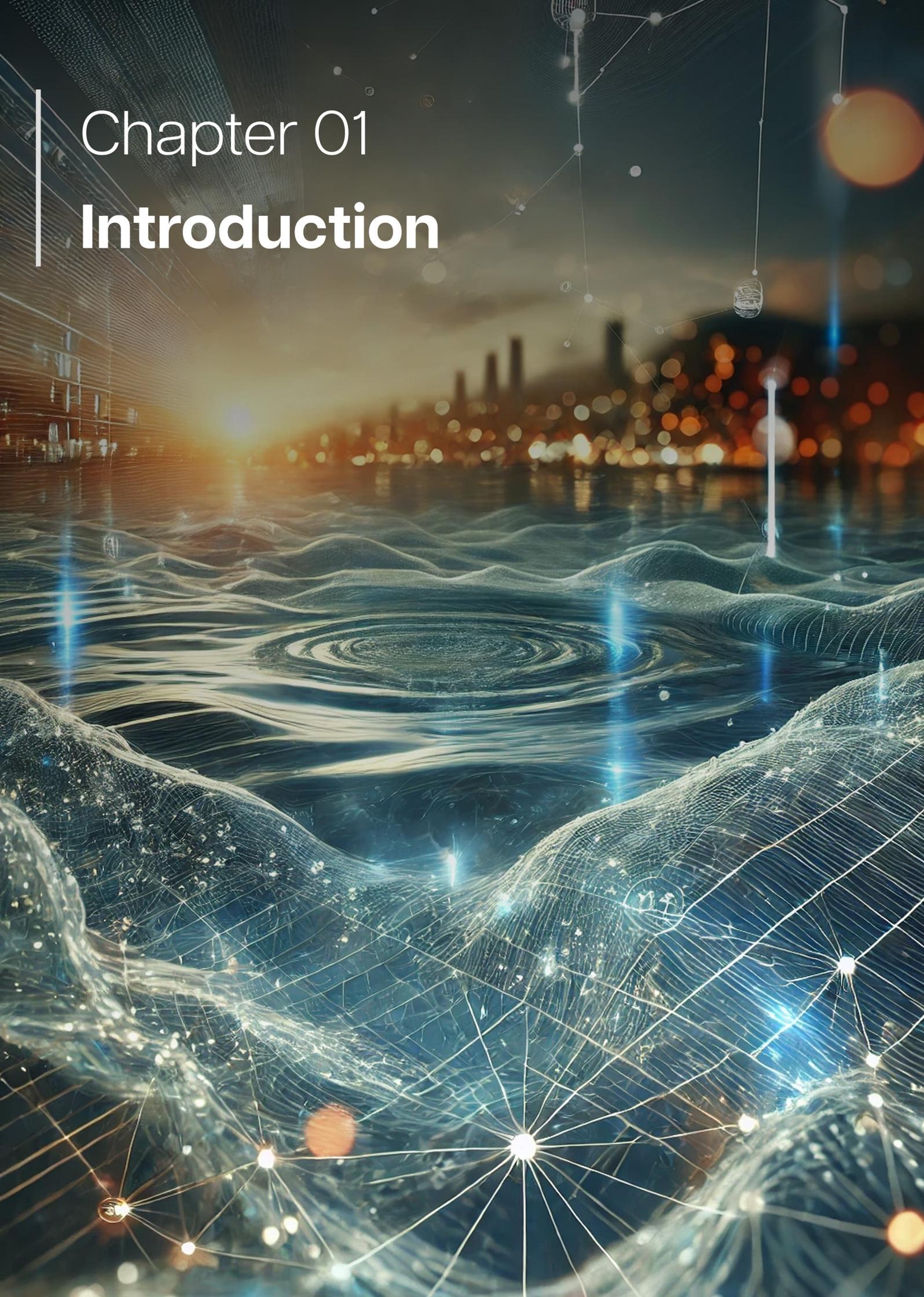
Looking Ahead – A Future with Digitally Enabled Water Utilities

Investment in water yields significant dividends. The **African Union estimates that every \$1 invested in climate resilient water and sanitation returns at least \$7 in societal and economic gains¹²** through improvements in health, energy, food security, environment, gender equality, and sustainable development goals.

Achieving a sustainable, digitally driven water sector requires collaboration between utilities, governments, and development partners. **While digital transformation presents a significant opportunity to modernize utilities, key challenges** – financial instability, inefficient fund allocation, lack of enabling policies, and workforce skill gaps – **must be addressed collaboratively to unlock its full potential.** Many utilities, especially in emerging markets, struggle to attract investment due to low creditworthiness and reliance on limited government funding. Inefficient planning, regulatory barriers, and workforce skill gaps further hinder digital adoption. Overcoming these challenges requires mobilizing funding, strengthening institutional capacity, and fostering an ecosystem for sustainable digital transformation.

To drive meaningful change, **utilities** can develop comprehensive digital strategies, advocate for policy reforms, and strengthen workforce capabilities through upskilling and partnerships. **Governments** can play an important role in establishing supportive policies, cost-reflective tariffs, and regulatory incentives that foster private sector participation and investment. Meanwhile, **development partners** can enable utilities to accelerate digital transformation by providing financial support, technical expertise, and capacity-building programs while working with governments to create an enabling environment for investment and innovation. By aligning efforts, mobilizing resources, and fostering innovation, stakeholders can ensure that water utilities become more efficient, financially sustainable, and resilient – securing access to clean water for future generations.

¹²African Union. Retrieved from: [African Union Commission \(AUC\) / Press release | Global leaders say Africa can achieve water security by 2030, present three pathways supported by action plan](#)



Chapter 01

Introduction

Water is the lifeblood of our planet and is critical to our survival, yet it remains an elusive privilege for millions, underpinning an urgent need for systemic changes. WHO and UNICEF¹³ predict that ~785 million people worldwide do not have basic access¹⁴ to water. Annually, more than one million people¹⁵, primarily infants and children, die due to lack of access to safe water and sanitation. Beyond the public health concerns, the societal implications of water inaccessibility are profound, as women and young girls spend roughly 200 million hours¹⁶ every day, carrying a disproportionate load of the labor-intensive task of water collection. As the urban population expands¹⁷ from 30% of global population in 1950 to an anticipated 68% by 2050, the demand for water is surging, making it increasingly difficult to ensure urban water supply coverage. Furthermore, climate change threatens to intensify water shortages, particularly in regions already facing water scarcity.

Despite the critical importance of water, the world faces an impending crisis: if current trends persist, global water demand is projected to exceed supply by 40% within the next five years¹⁸.

Water utilities, which are responsible for ensuring the provision of safe water and managing wastewater treatment, serve as a critical part of water resource management. **Many utilities today, especially in the emerging market, face several critical challenges, which include but are not limited to:**

- High rate of Non-Revenue Water (NRW)¹⁹ due to leakages, theft, and billing inaccuracies causing substantial losses in potential revenue.
- Inefficient processes and inadequate monitoring systems that leading to water contamination or unavailability, harming public trust and health.
- Non-cost reflective tariff structures and ineffective revenue collection mechanisms, resulting in a low or negative net-income margin, threatening financial sustainability.

These are just a few of the challenges that confine the utilities into a **vicious cycle**: declining service quality leads to reduced consumer trust, operational struggles, and a failure to accumulate necessary funds, which in turn prevents service improvements.

¹³Source: WHO, UNICEF. Retrieved from: [Billions of people will lack access to safe water, sanitation, and hygiene in 2030 unless progress quadruples – warn WHO, UNICEF](#). ¹⁴Access is defined by UNICEF as safe, attainable, and affordable water from a reliable source (well, tap, hand pump), free from fecal or chemical contamination, available >12 hours a day, and within reasonable reach. ¹⁵Source: WHO. WHO estimates that access to safe drinking water, sanitation, and hygiene services could have prevented 1.4 million deaths in 2019. Retrieved from: [Water, sanitation and hygiene: burden of disease](#). ¹⁶Source: Water.org. Retrieved from: [The Water Crisis: Shortage, Problems & Solutions | Water.org](#). ¹⁷Source: United Nations. ¹⁸Source: United Nations. Retrieved from: [Half the World to Face Severe Water Stress by 2030 unless Water Use is “Decoupled” from Economic Growth, Says International Resource Panel](#). ¹⁹NRW rate refers to the % of water volume that was not subject to billing in relation to the volume distributed

JICA believes²⁰ that digitalization of utilities can help improve their operations, customer service, support functions, and investment strategies, thereby getting them out of this vicious cycle and putting them in a **growth spiral**. Given the rapid advancement of modern technologies, coupled with the growing trend towards leveraging tools such as Artificial Intelligence (AI), the Internet of Things (IoT), and predictive analytics, it is imperative for utilities to move towards a paradigm that harnesses digital and data capabilities to face the challenges of today and fulfill the evolving future needs. JICA aims to leverage digital and data to enable water utilities to offer improved services to the citizens, improve their financials, expand their service area, reduce dependence on subsidy and aid, and become self-sustaining entities that can move the needle towards achieving the SDG 6.¹²¹

1.1 Purpose of the Report

This report focuses on the transformative potential of digitalizing water utilities, a strategy championed by JICA to bolster global water sustainability efforts. It presents a comprehensive exploration of the opportunity and methodology of digital transformation across the value chain for water utilities. The report highlights the major pain points of water utilities today, focusing in-depth on how technology can be leveraged to address them. The report provides a reference digital technology architecture, five-level framework for assessing the digital maturity of utilities, set of potential initiatives to consider in their journey, guiding principles for successful digitalization, and case studies of utilities undergoing digital transformation. **The content of this report is designed to be relevant for utilities across all stages of digital maturity, from those primarily relying on paper-based and legacy systems to digitally advanced utilities.**

This report aims to be a catalyst for digitalization in the water sector, inspiring substantial progress and innovation in the modernization of water utilities around the world, moving us closer to a world in which access to clean water is universal and guaranteed for all.

1.2 About the Report

This report draws on the extensive knowledge base of the Japan International Cooperation Agency (JICA) in working with water utilities globally, enriched through a partnership with the Boston Consulting Group (BCG) to develop a comprehensive Data Strategy and Digitalization Roadmap for utilities in South Asia and Africa. **The report distills insights from JICA's engagements with over 50 utilities²², augmented by detailed stakeholder consultations and a thorough global benchmarking exercise, incorporating both primary and secondary research.**

Our consultations involved a broad spectrum of international experts and major players in the water utilities space, including policymakers, utility leaders, academicians, Original Equipment Manufacturers (OEMs), influential think tanks, and prominent donor agencies. These consultations have enabled us to provide a multi-faceted view of the challenges and opportunities in digitalization of water utilities at all levels of digital maturity.

²⁰To read more about JICA's outlook on supporting water utilities, please check: [JICA Cluster Strategy](#).

²¹Universal and equitable access to safe and affordable drinking water for all.

²²Read more about JICA's work utilities worldwide here: [Case Studies of JICA's Support for Growth of Water Utilities](#).

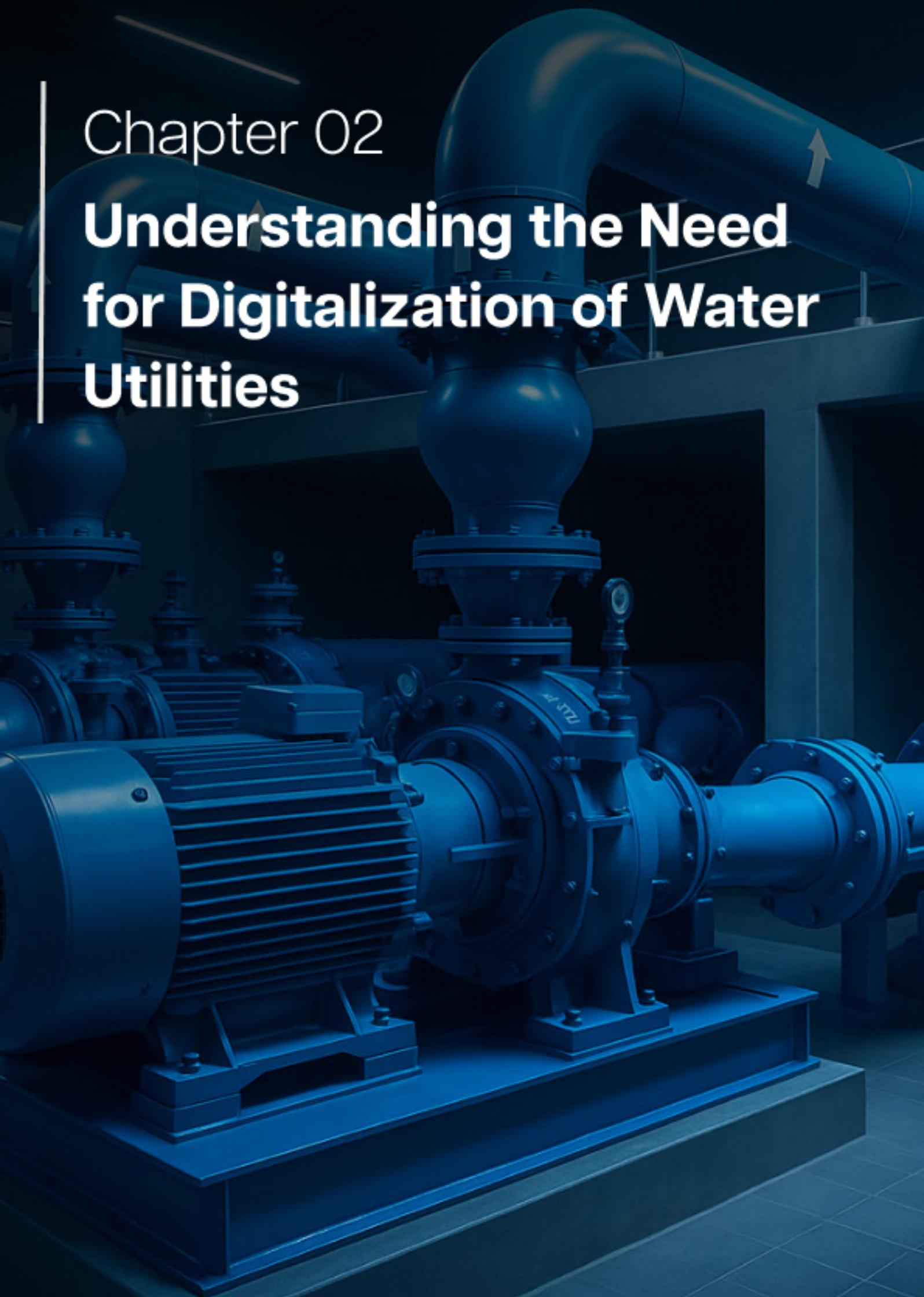
We also benchmarked digitalization efforts of water utilities in over a dozen countries, including Japan, Bangladesh, India, South Africa, Thailand, Tanzania, France, among others. This global benchmarking revealed common threads that have led to successful digitalization outcomes, as well as pitfalls that can beset well-intentioned efforts to digitalize.

1.3 Using the Report

This report offers actionable insights and practical steps for stakeholders to work towards ensuring sustainable water security globally by driving the digital transformation of water utilities.

As a shared global resource, water transcends national borders, and its mismanagement can lead to far-reaching consequences. Lack of access to clean water supply may spark public health crises, fuel the spread of communicable diseases, and drive large-scale human migration that can create ripple effects beyond national boundaries. Addressing a challenge of this scale demands more than fragmented efforts – only coordinated, collective action from utilities, governments, and development partners can create meaningful and lasting change. This report aims to serve as a guide for utilities, governments, and development partners in enabling the digital transformation of water utilities.

- **Utilities** can leverage the frameworks and approaches outlined in this report to assess their current digital maturity, envision a future state of digitalization, develop a comprehensive long-term plan tailored to their specific needs, and attract donors to finance their efforts.
- **Governments** can utilize this report to grasp the critical need for and value of digitalization within utilities, incentivize utilities to undertake effective digitalization initiatives, and establish supportive regulations and policies that facilitate profitable and sustainable digital transformation.
- **Development Partners** can identify crucial capabilities and support systems necessary for successful digital transformation, while assessing the potential costs and impacts of investing in the digitalization of water utilities.



Chapter 02

Understanding the Need for Digitalization of Water Utilities

In **Chapter 1**, we briefly highlighted the pressing challenges facing water utilities—ranging from high Non-Revenue Water (NRW) losses and financial instability to operational inefficiencies – keeping many utilities trapped in a **vicious cycle** of underperformance. We introduced **digitalization** as a transformative solution that can shift utilities toward a **growth spiral**, improving efficiency, financial health, and service delivery.

This chapter explores **how digital transformation can address these challenges**, examining **major pain points and KPIs** across the utility value chain and outlining opportunities for utilities to enhance operations, financial sustainability, and service quality through digital solutions. We define **what digital transformation for water utilities looks like** and introduce a **comprehensive digital maturity framework**, classifying utilities into five levels based on their current capabilities across six key parameters. We also present an **ideal digital technology architecture** to guide utilities in designing and implementing effective digitalization strategies.

Finally, we map out the **journey from a Legacy to a Digitally Advanced Utility**, outlining the potential initiatives and capability enhancements needed at each stage. As utilities progress along this path, we explore **how AI and Generative AI can further amplify value**, enabling smarter decision-making, predictive maintenance, and optimized resource management across the entire water ecosystem.

2.1 Need for Progress: The Business Pain Points of Utilities Today

Water utilities lose over 126 billion cubic meters of water annually, with the average utility losing almost one-third of its treated water due to leakages or unbilled consumption²³.

Water utilities play a crucial role in water management, responsible for delivering clean, safe water to communities and overseeing wastewater treatment to protect public health and preserve the environment. However, reliance on aging infrastructure, non-cost-reflective tariffs, and decades of underinvestment has left many utilities struggling with inefficiencies, mounting operational losses, and unsustainable levels of water loss. Furthermore, **progress is often hindered by substantial financial shortfalls and limited coordination**. Water infrastructure development relies on the “**3Ts**” – **Tariffs, Taxes, and Transfers** – as primary funding sources, yet each comes with challenges. **Tariffs**, the fees consumers pay for water services, provide a predictable revenue stream that, when set at cost-reflective levels, allow utilities to cover operational costs and reinvest in infrastructure. However, in many cases,

²³Source: International Water Association. Retrieved from: Quantifying the global non-revenue water problem | Water Supply | IWA Publishing

tariffs are too low to sustain financial viability, forcing utilities to depend on external funding. **Taxes**, allocated from government budgets, often subsidize water services, especially for low-income populations, but excessive reliance on them places pressure on public finances and limits long-term sustainability. **Transfers**, including international aid, grants, and concessional loans, are vital for utilities in emerging economies but are often unpredictable and unsustainable as a primary funding mechanism.

Meeting the SDG targets for universal access to safe water and sanitation requires an additional USD 131.4 billion to USD 140.8 billion in annual funding to bridge the current investment gap²⁴.

A major concern is the high Non-Revenue Water (NRW) levels, which lead to utilities struggling to generate sufficient revenue. **Globally, an estimated 126 billion cubic meters of water is lost each year, resulting in nearly \$39 billion in financial losses annually²⁵.** Today, many utilities in the world operate with limited end-to-end visibility of the value chain of water, from production to consumption and billing. The lack of integrated systems across the value chain means that physical and commercial losses are difficult to accurately trace, and even harder to address. **The World Bank projects²⁶ that a typical water utility loses USD 21.38 Million annually due to the “hidden cost” of inefficiencies.** Beyond its significant economic toll, high Non-Revenue Water and inefficiencies severely limit the ability of water utilities to expand their coverage and enhance service delivery. In the face of escalating water scarcity and climate change, this inefficiency threatens progress toward universal access to reliable and affordable water services.

The challenges faced by water utilities may vary significantly based on their stage of development²⁷. Utilities at an earlier stage typically have basic service delivery infrastructure in place but service levels are comparatively lower. These utilities often grapple with issues such as infrastructure development, limited funding availability to improve operations and maintenance capacity, high NRW rates, and low tariff levels leading to negative profitability. In contrast, more mature utilities that have robust infrastructure in place and have reached comparatively higher level of service delivery encounter challenges related to service expansion planning, management efficiency, customer satisfaction, and generating sustainable profits from operations.

The strategic objectives of water utilities are to ensure consistent and high-quality water supply 24/7, expand service coverage to underserved areas, promote water conservation and sustainable usage, provide reliable customer service, maintain enterprise readiness, continuously develop workforce capabilities, and operate in a financially sustainable manner with reasonable water tariffs. However, utilities with marginal or negative profits often find themselves in a **vicious cycle** that impedes them from reaching these objectives.

²⁴Source: World Bank. Retrieved from: [Funding and financing in the water sector. Revisiting the challenges and opportunities for the coming decade - Latitude](#). ²⁵Source: International Water Association. Retrieved from: [Quantifying the global non-revenue water problem | Water Supply | IWA Publishing](#). ²⁶Source: World Bank; retrieved from: [Why investment in water is crucial to tackling the climate crisis | World Economic Forum](#). ²⁷To read more about Stages of Development for Water Utilities, please check out Chapter 3: Development Scenario and Key Concepts, from the [JICA Cluster Strategy](#)

Insufficient funds and limited attractiveness to external financiers or donors hinder the utilities’ ability to improve infrastructure, management, and service levels. In turn, this leads to public dissatisfaction and erodes trust, which stymies their ability to generate reliable income from operations.

Investment in digital technologies can break this cycle and set utilities on a **growth spiral** by addressing critical pain points across the value chain. This empowers them to evolve into **growing water utilities**²⁸, which can generate predictable income from their operations, reduce dependency on subsidies and aid, and raise funds through retained earnings, bond issues, and direct borrowing. The exhibit below summarizes the key pain points and major KPIs for Water Utilities across its value chain. As established already, the severity of these challenges for a utility will be dependent on its current stage of development.

Major KPIs and Pain Points for Water Utilities

Operations

Value Pool →	Assets and Investments	Production	Distribution	Collections and Customer Support	Management/ Support Function
Description	Physical/ Digital Infra, CAPEX, Project Planning and Mgmt, Procurements	Water Sourcing, Treatment, Storage in reservoirs	Pumping Mains, Distribution to end-consumers	Registration & Authorisation, Metering, Billing & Payment, Complaints & Queries	Finance, HR, Supply Chain, etc
Major KPIs	Operational Downtime Rate	Cost Per Unit Water Treated	Water Loss Percentage	Metering Efficiency	Number of employees completing capacity development program
	Asset Utilization Rate	Water Quality standard compliance rate	Average service hours per day	Collections and Billing Efficiency	Employee Satisfaction Index
	Revenue loss due to inadequate inventory	Daily Liters of Production per person in service area	Water Supply Coverate Rate	Customer Satisfaction Index	Audit compliance rate
	Mean Time Between Failures	Energy Efficiency Ratio		Cost Recovery Ratio	Staff Per 1000 Connections
	Capital Investment Per Connection	Non Revenue Water %			Technology adoption rate
Pain Points	Aging Infra/ Outdated Technologies	Inefficient treatment processes	Loss of treated water due to pipeline issues/ breakdowns	Inaccurate bill generation	Limited digital skillset of workforce
	Inefficient Investment and Expansion	Contamination and poor quality of intake water	Limited reach of distribution network	Unreliable customer data and unauthorized connections	Demotivated workforce
	Lack of adequate inventory for maintenance	Depleting sources of supply (e.g., river, groundwater)	Distribution challenges (e.g., water pressure mgmt.)	Unresolved customer concerns and long response time	Governance issues and mismanagement
	Inefficient Maintenance Planning	High and irregular energy consumption in production and distribution		Non Cost-reflective tarriffs	Low workforce productivity
	Insufficient Fund Availability	High non-revenue water rates due to theft, leakages, meter failures			Resistance to change and tech adoption

Directly Addressable by Digitalization

Figure 6: Major KPIs and Pain Points for Water Utilities

²⁸To read more about how JICA Support the Growth of Water Utilities, please go through the [JICA Cluster Strategy](#)

While significant improvements can be realized from digitalization across the value chain, as evident in the exhibit above and will be further detailed in Chapter 3, **digitalization is not a cure for all challenges faced by water utilities**. This report emphasizes the digital transformation of utilities, but it is crucial to recognize that utilities must also continue to invest in critical facets such as upgrading their physical infrastructure and improving customer metering rates. These efforts complement digital advancements, ensuring utilities can fully leverage the potential of digitalization. Moreover, it is imperative for utilities to strive towards tackling broader challenges, such as low tariff rates and depleting water sources, which digital solutions cannot directly resolve. **Digital transformation will serve as a powerful multiplier when it is paired with ongoing efforts to enhance other critical infrastructural, operational, and strategic aspects of water utilities.**

2.2 Understanding Digital Transformation: What Does It Mean for Water Utilities

Digital transformation of water utilities is a strategic process that entails a comprehensive integration of digital technologies across the value chain, the development of robust technological governance, and robust capacity building within the workforce to utilize digital advancements for enhancing operational efficiency, customer service, and sustainability. This transformation involves the systematic use of digital tools to streamline processes, improve data collection and analysis, and enable more informed decision-making. It includes everything from basic digitization of records and automation of meter readings to more complex system integrations and Data Analytics to drive advanced use-cases such as predictive maintenance of pipelines to minimize leakages. Additionally, this transformation includes strengthening governance structures to ensure accountability and transparency in use of digital technologies, as well as investing in capacity building to equip the workforce with necessary digital skills. By adopting digital technologies in a strategically planned manner, utilities can improve the management of their resources, reduce losses, enhance customer interactions, adapt more effectively to evolving environmental and regulatory challenges, and improve their bottom-line.

2.3 Becoming Future-Ready: Ideal Tech Architecture for Utilities

To effectively tackle business pain points through digitalization, it is crucial to understand the technology architecture and capabilities required for a digitalized utility. This understanding will help in building an organization that is well-suited to enable specific digital use-cases. In this section, we outline a Reference Digital Technology Architecture that details ideal end-state components across six key layers. The six layers include:

6 Layers of Digital Tech Architecture for Water Utilities

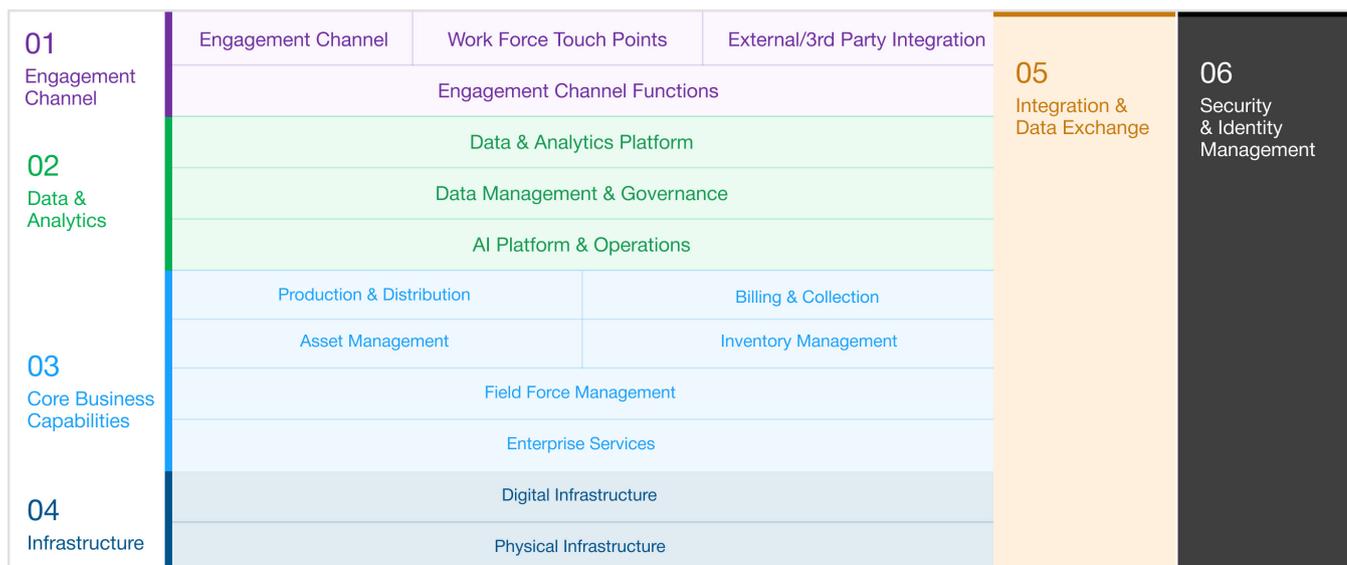


Figure 7: High-level digital technology architecture for Water Utilities

In the high-level architecture for water utilities presented above, the layers of Engagement Channels, Data and Analytics, and Core Business Capabilities are dedicated to developing and implementing targeted digital solutions that address specific challenges across the utility value chain, from production through to billing and customer service, as well as the support functions. Conversely, the layers of Infrastructure, Integration and Data Exchange, and Security and Identity Management serve a foundational role by enabling and supporting the effective implementation of these solutions.

The subsequent pages provide a deeper dive into the digital architecture for water utilities. **It is important to note that the individual systems/components listed here are not exhaustive. Only key components of the target digital architecture for a water utility have been included to provide a simplified, clear, and focused overview.** Throughout the digital transformation journey, utilities will gradually develop their technology architecture. Each utility may need to modify or expand upon these components based on specific operational needs and geographic realities.

1. Engagement Channels

Engagement Channels help utilities connect efficiently with customers, employees, and external partners like government and weather agencies. These channels include apps, emails, call centers, chatbots, and online portals, making communication and services more accessible and seamless.



Figure 8: Engagement Channels

An example of a customer touchpoint as shown in the system / component architecture above is given below:

- Customer Servicing Portal: A self-service web portal where customers can check their billing, payments, water usage, and request services.

The details related to all the systems / components in this layer can be referred in Appendix A, Layer 1: Engagement Channels.

2. Data and Analytics

The Data and Analytics layer **handles everything related to data – collecting, storing, organizing, and analyzing it.** It also includes AI tools to help make smarter decisions and improve services.

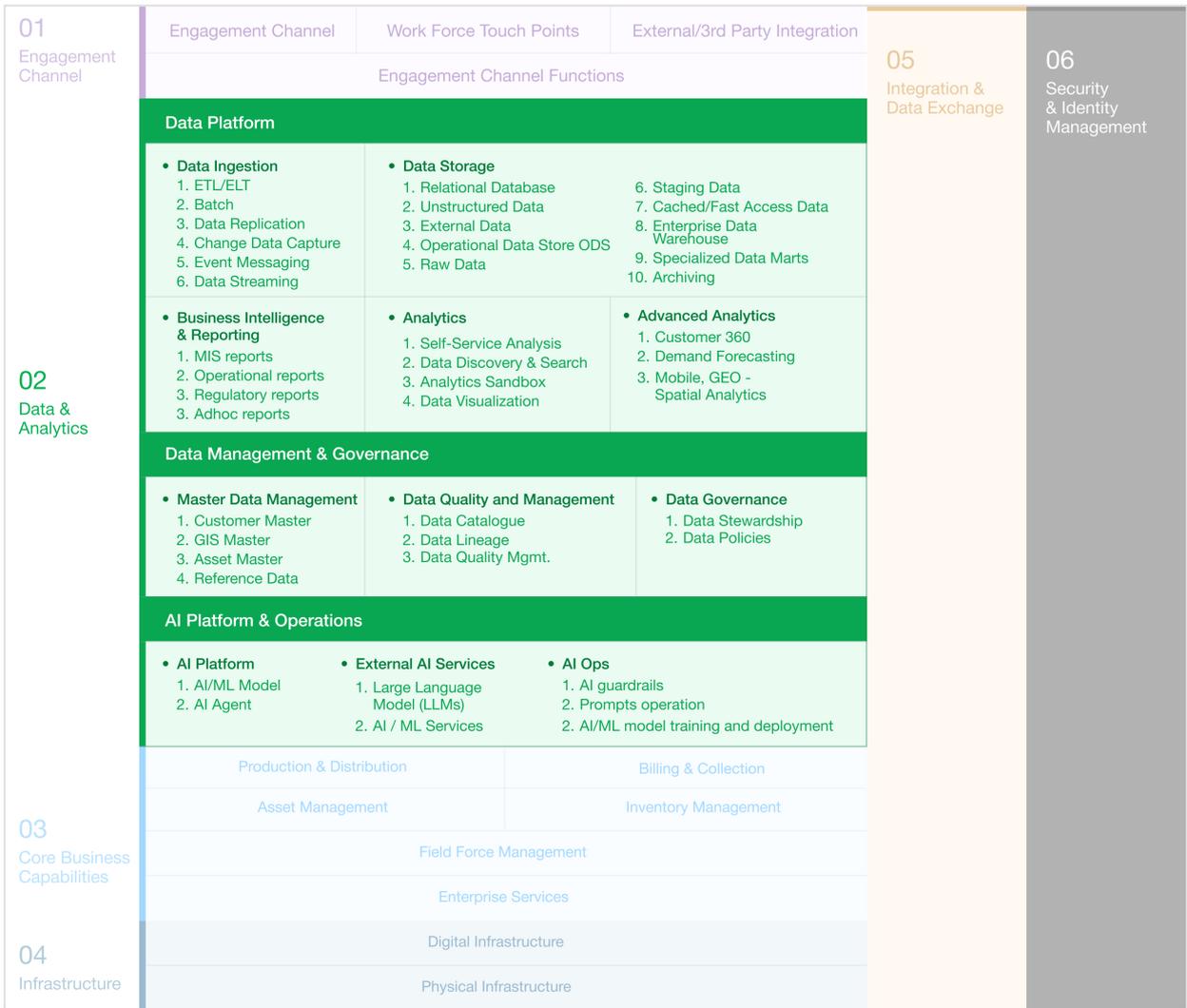


Figure 9: Data and Analytics

Data Platform: This component serves as the single source of truth for storing, managing, and accessing all water utility-related data. It leverages data ingestion tools to integrate data from core business systems, IoT devices, SCADA systems, GIS, CRM, and financial systems into a unified ecosystem. An example of the data ingestion system and one of the capabilities it brings is given below:

- **Data ingestion:** Ensures that data from smart meters, SCADA systems, IoT sensors, weather services, and customer platforms is accurately collected, cleaned, processed, and delivered to different applications. One such capability of a data ingestion system is:
 - **ELT / ETL:** ETL (Extract-Transform-Load) / ELT (Extract-Load-Transform) tools enable ingestion of data covering capabilities such as cleansing, normalizing, and enrichment of data from source systems before storage.

The details related to all the systems / components in this layer can be referred in Appendix A, Layer 2: Data and Analytics.

3. Core Business Capabilities

The Core Business Capabilities Layer forms the foundation of water utility operations, ensuring the efficient management of water production, distribution, metering, revenue collection, asset lifecycle management, inventory handling, field workforce operations. Additionally, it includes critical support functions within the ERP layer, such as finance, procurement, human resources, governance, and compliance.



Figure 10: Core Business Capabilities

Digital transformation of these core business processes enables utilities to optimize performance, reduce losses, and enhance service delivery.

Production and Distribution: Water production involves the sourcing, treatment, and supply of water to ensure a sustainable and high-quality water supply. Water distribution involves the efficient and equitable delivery of treated water to various types of consumers. Example of a key system involved in digitalization of production management is given below:

- **SCADA Systems for Real-Time Monitoring:** Tracks flow rates, pressure, and water quality metrics.

The details related to all the systems / components in this layer can be referred in Appendix A, Layer 3: Core Business Capabilities.

4. Infrastructure

The Infrastructure layer includes both physical and digital assets. **Physical Infrastructure** consists of pipes, pumps, and reservoirs that support water distribution and treatment. **Digital Infrastructure** includes IT networks, cloud systems, and cybersecurity tools that enable digital operations and data management.



Figure 11: Infrastructure

A modern water utility leverages **Smart meters and IoT sensors** to monitor the water quality, assets and inventory involved in water production and distribution core processes that enable real time monitoring for seamless service delivery. One of the **key components of digital infrastructure** is given below:

- **IoT Sensors and IoT Gateway:** Water utilities may use various types of sensors such as flow sensors, pressure sensors, water quality sensors (pH, turbidity), GIS and other devices to enable real time monitoring. An IoT gateway is a device that connects IoT sensors and devices to the internet, enabling data transmission and communication.

The details related to all the systems / components in this layer can be referred in Appendix A, Layer 4: Infrastructure.

5. Integration and Data Exchange

The Integration Layer in a water utility **ensures seamless communication** between different IT systems, IoT devices, SCADA, ERP, smart meters, customer portals, and external third-party services. It **acts as the backbone for data exchange, automation, and interoperability**, ensuring that critical business processes run efficiently.



Figure 12: Integration and Data Exchange

By leveraging API orchestration, event-driven messaging, encryption, and secure data transfer, water utilities can enable real-time monitoring, automated billing, predictive maintenance, and regulatory compliance. One example of the key systems that enable integrations is given below:

- **Event Driven (Pub-Sub) Integration:** Manages event-driven messaging between systems, ensuring real-time data updates and alert notifications. Enables real time data streaming by using technologies such as Kafka, MQTT etc.

The details related to all the systems / components in this layer can be referred in Appendix A, Layer 5: Integration and data exchange.

6. Security and Identity Management

As utilities increase their reliance on digital technologies, securing these systems and managing access becomes imperative. Security in a modern water utility is critical to protect operational technology (OT), IT systems, IoT infrastructure, customer data, and financial transactions from cyber threats, unauthorized access, and compliance risks.

The **Security and Identity Management** layer ensures safe access to critical systems like SCADA, ERP, IoT devices, and customer portals. It includes multi-layered authentication, role-based access, single sign-on, encryption, and cybersecurity governance, enabling utilities to comply with relevant data regulations (e.g., GDPR, ISO 27001, NIST).



Figure 13: Security and Identity Management

An example of the key capabilities enabled by this layer is given below:

- **Authentication:** Verifies user and system identities before granting access to water utility applications, control systems, and cloud platforms. Also provides capabilities such as multi-factor authentication, federated identity management to prevent unauthorized access.

The details related to all the systems / components in this layer can be referred in Appendix A, Layer 6: Security and Identity management.

In this section, we provided a detailed breakdown of the components available to a utility when it has reached an ideal end state of digitalization. However, what systems and components are present in the technology architecture of a utility will be dependent on its digital maturity. In the subsequent pages, we will explore a framework for digital maturity of utilities, provide strategic guidance on what a utility should focus on at each level of maturity, and revisit the overall target architecture to see what capabilities are typically seen for utilities at different levels of maturity.

2.4 Digital Maturity Framework: The 5 Levels of Digital Maturity for Water Utilities

To effectively navigate the path of digital transformation, utilities need to understand where they stand in terms of their digitalization today. We have created a structured framework to determine digital maturity of a utility. At the end of this section, we will provide a Digital Maturity Assessment tool that will enable utilities to assess their as-is and to-be states for digitalization with a sample evaluation.

Digital Maturity Framework: 6 Parameters to Assess Digital Maturity

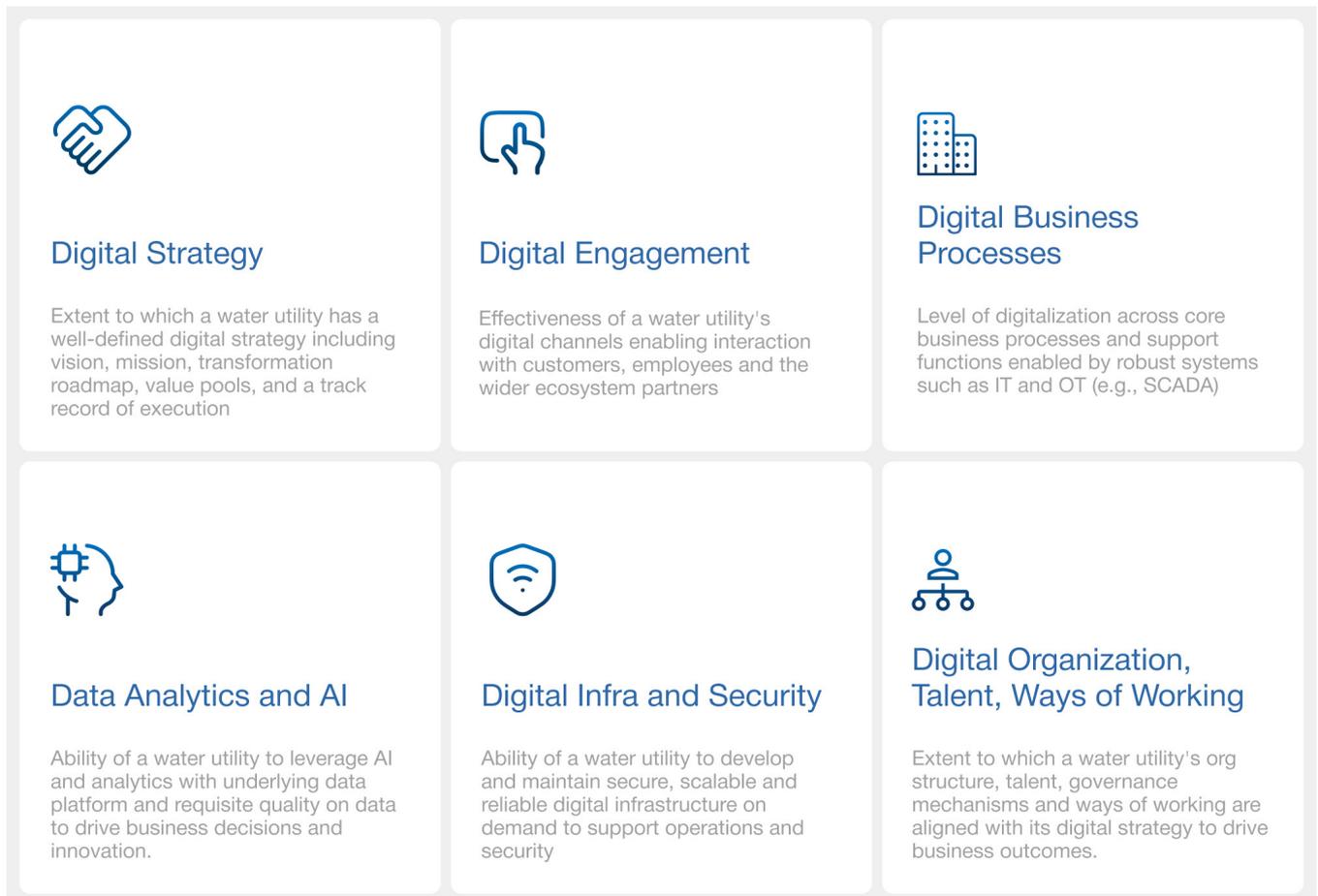


Figure 14: Six parameters that influence the digital maturity of utilities

Using these parameters as a framework, utilities can be segmented into the following five distinct levels of digital maturity:

- **Legacy (Level 1):** At this foundational level, utilities operate with minimal digital intervention, relying predominantly on manual processes to drive core business processes such as production, distribution, and revenue generation.
- **Basic Digitalization (Level 2):** At this stage, utilities begin to adopt digital tools to automate select business processes, although these efforts are often siloed and lack a cohesive digital strategy.

Intermediate Digitalization (Level 3): Utilities at this level begin to adopt a digital strategy and work towards automating several core and support functions, enhancing digital engagement, and building centralized data management capabilities.

Digitalization (Level 4): Utilities reach the mature state when they have almost fully digitalized their core and support functions and initiated advanced analytics (AI) to drive data-driven decision making through the organization.

Advanced Digitalization (Level 5): Representing the most advanced level of digital maturity, utilities at this level employ cutting edge technologies (IT and OT) to drive value creation and have established interoperable systems enabling seamless integration with other utilities and ecosystem partners.

The following exhibit provides an overview of how utilities in each level of digital maturity perform across the six parameters:

Digital Maturity Framework: Competencies for 5 Levels of Maturity

	Legacy	Basic Digitalization	Intermediate Digitalization	Digitalization	Advanced Digitalization
Digital Strategy	No defined strategy in place	Siloed digitalization initiatives but no overarching strategy or org-wide focus on digitalization	Strategy in place with well-defined roadmap & value case (including KPIs) Execution underway	Strategy in place with proven track record of execution and value realization	Strategy continuously refined with learnings from execution, value realized & industry trends
Digital Engagement	No digital channels for customer or employee engagement	Introduction of assisted comms channels (e.g., call center) and SMS / email based comms	Self-service capabilities through web portals and mobile apps e.g. customer portal	One-stop digital engagement e.g. end-to-end customer lifecycle / relationship management	Holistic digital engagement with customers, employees, and external stakeholders e.g., weather services
Digital Business Processes	Paper-based core business processes (e.g., production, distribution, and metering); limited to no automation	Siloed digitalization across core business processes (via SCADA, Asset mgmt. etc.); however, significant manual work persists	Increasing digitalization of core processes (e.g., billing NRW) & support functions through ERP & other industry standard systems	Majority of business processes are optimized & digitalized through advanced systems (e.g., VFD, PLC, Hydraulic Modelling) leveraging AI	State-of-the-art digital platforms, continuous improvement and feedback cycles in place
Data Analytics & AI	Manual and non-standardized data recording in silos. Basic financial and operational reports, generated manually	Foundational data platform (e.g., RDBMS, ODS) used; data quality issues persist. Select financial and operational reporting automated	Centralized data platform with improved data quality for BI - Analytics (e.g., NRW, Mgmt. Dashboard)	Data-driven decisions leveraging AI/ML models, high-quality data across core business processes (e.g., demand forecasting, early warning systems)	Leverage ecosystem data (e.g., weather, satellite) to drive more accurate, holistic AI/ML predictions; seamless interoperability with data exchange
Digital Infra and Security	Siloed IT infra with limited security controls	Basic digital infra (e.g., IT device mgmt.) with basic security controls and reactive approach to incidence response	Standard digital infra (e.g., IoT sensors) with well defined security controls, & regular audits	Optimized digital infra (e.g., Ultrasonic flow meter, Smart Meter) leveraging AI based capacity planning & predictive security controls	Autonomous, self-healing digital infra with threat intelligence for seamless and secure integration with ecosystem partners
Digital Organization, Talent, Ways of Working	No dedicated full-time IT / digital team; only basic infra / operational maintenance capabilities	Small IT/ digital team (<5 people) to run basic digitalization initiatives and O&M	Medium sized IT team with select digital skills; few digital programs driven with program level governance	Strong IT / Digital teams with strategic sourcing and capability to execute digital programs and innovation agenda	State of the art digital capabilities built (e.g., Innovation Lab, AI CoE); large programs successfully done

Figure 15: Digital Maturity Framework; Competencies for 5 levels of Maturity

It is important to recognize that a utility that has achieved a specific level of digital maturity may not necessarily perform at that level for all the 6 parameters. Utilities may advance more rapidly in certain parameters while experiencing slower progress in others. This variability underscores the complex, multi-faceted nature of digital transformation within utilities, where progress can be advanced in some areas while still developing in others.

Leveraging the framework above, utilities can assess their current level of digital maturity. For reference, we are providing a maturity assessment for a sample utility based in South Asia:

Assessment of Digital Maturity for a South Asian Utility

Parameter	L1	L2	L3	L4	L5	Remarks
01 Digital Strategy						<ul style="list-style-type: none"> Digital Strategy has been developed, execution underway for select foundational initiatives.
02 Digital Engagement						<ul style="list-style-type: none"> SMS and phone based communications used, no full fledged CRM and Employee Mgmt. Portal
03 Digital Business Processes						<ul style="list-style-type: none"> Core processes being digitalized gradually, NRW monitoring tool being piloted; Partial network under SCADA, limited digitization of support systems
04 Data Analytics and Artificial Intelligence						<ul style="list-style-type: none"> Foundational data ingestion systems in place, limited BI and analytics capabilities; no AI platform in place
05 Digital Infra and Security						<ul style="list-style-type: none"> Basic authentication, authorization, and access control present; limited cyber security governance
06 Digital Organization, Talent, Ways of Working						<ul style="list-style-type: none"> Traditional minded organization with limited trust on digitalization and innovation; Small IT/ Digital team
<ul style="list-style-type: none"> Assessment: The Utility is currently at a Level 2, gradually moving towards Level 3 						

Figure 16: Sample digital maturity assessment using the framework

2.5 From Legacy to Advanced Digitalization: How Utilities Can Move Forward in their Digital Transformation Journey

In the previous section, we examined the 5 levels of digital maturity for Water Utilities and how to assess the current maturity level of a utility. Once the as-is assessment is completed, utilities must move forward with a to-be vision. Depending on their current digital maturity, different initiatives and capabilities must be prioritized to progress in their digital transformation journey. In this section, we will explore how utilities at each level of digital maturity can strategically plan to advance their digitalization efforts.

Before we get into the initiatives and capabilities that could be prioritized at a given level of maturity, it is important to get a holistic view of the capabilities that are typically present across levels of maturity, on the overall digital architecture presented in section 2.3.

Target State Architecture

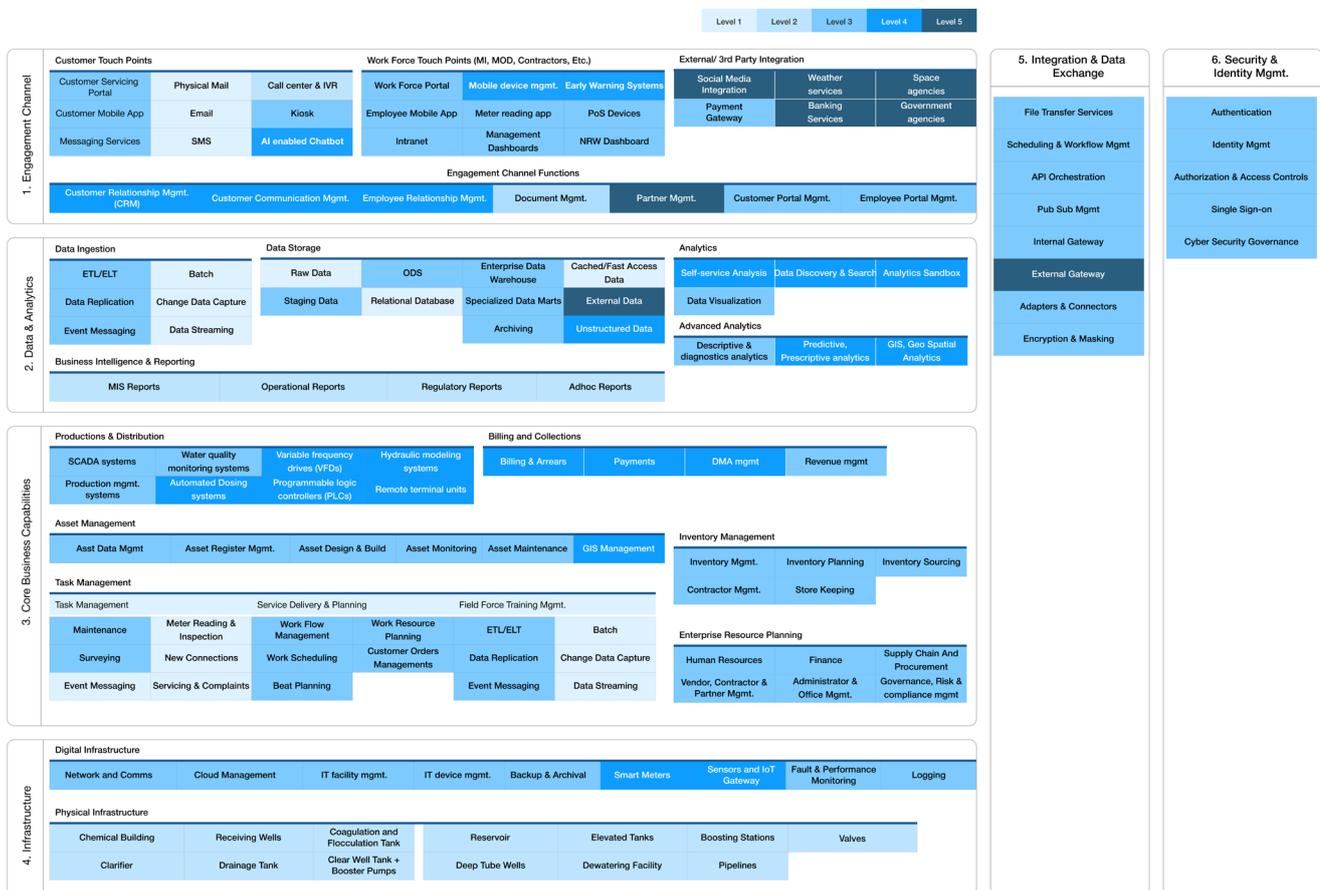


Figure 17: Target Tech Architecture for Water Utilities

The exhibit above presents a typical digital architecture for utilities at various stages of digital development. It is important to note, as already explained, that the specific adoption and implementation of these components can vary. Not all utilities will follow the exact same development path due to differing strategic priorities, resource availability, and context.

Now that we have understood the ideal end-state digital architecture, and the different levels of digital maturity for a water utility, we have explored below how utilities at each level of digital maturity can strategically plan to advance their digitalization efforts and progress to more advanced digital maturity levels. In the digital transformation journey of a typical utility, we can identify specific initiatives and capabilities that are crucial at each stage of maturity to set the foundation for progression to subsequent stages. **It is important to note that these initiatives will often be rolled out across several years in multiple phases, and a utility may graduate to the next level of maturity while continuing the implementation of the initiatives it had begun while in the previous level. Furthermore, we are only looking at potential initiatives here. Enablers such as capacity building of the workforce and digital governance will be covered later in Chapter 4.** The exhibit below provides a snapshot of an illustrative journey with a recommended, non-exhaustive list of initiatives that utilities might consider implementing based on their current stage of digital maturity, basis their individual context.

Focus Area and Suggested Initiatives for Advancement at Each Level of Digital Maturity

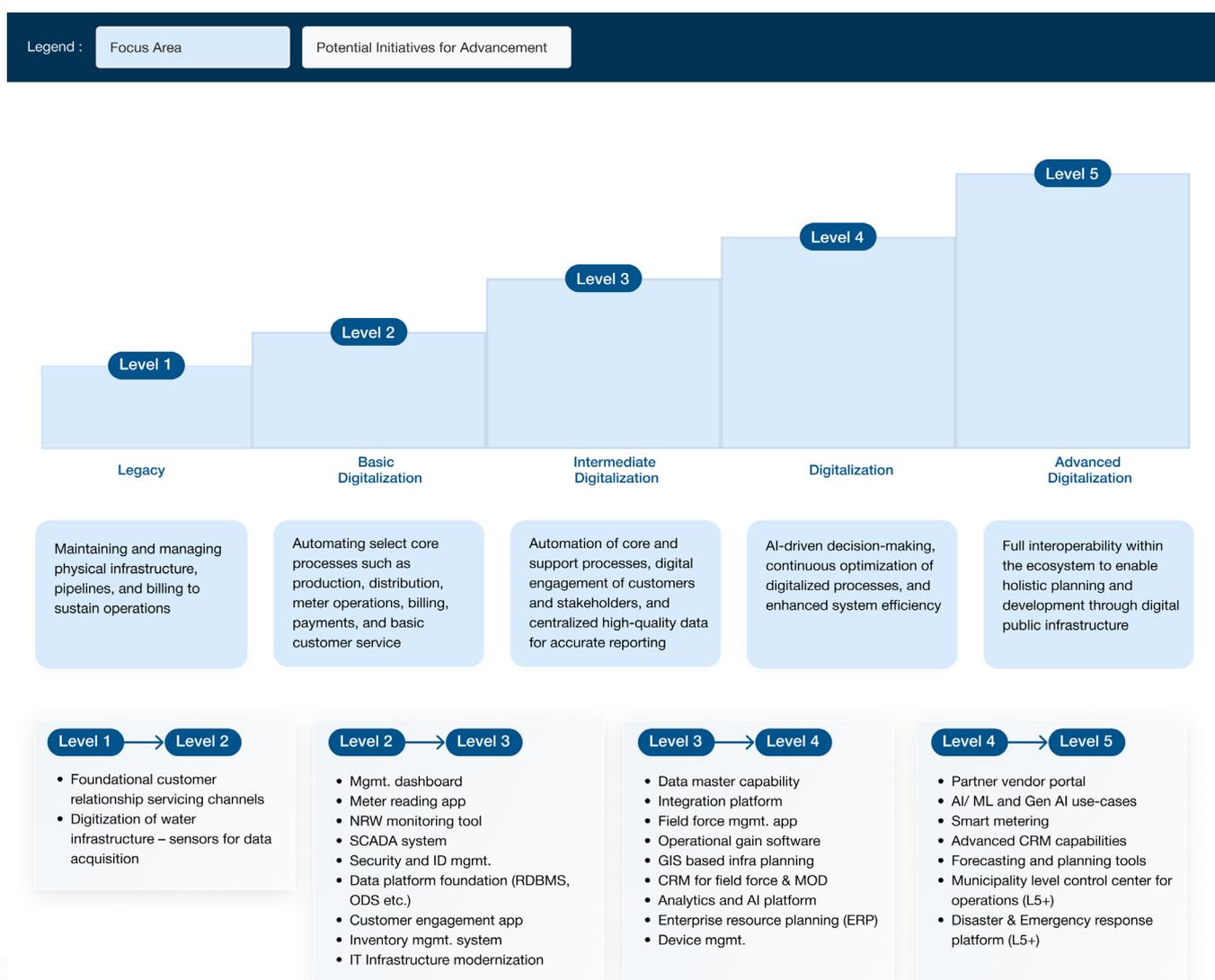


Figure 18: Sample digital maturity assessment using the framework

- **Level 1 to Level 2:** A utility at the Legacy level will predominantly rely on paper-based methods for all operational tasks. It will be focusing mainly on running the operations on physical infrastructure including storage facilities, pipeline, mechanical meters etc. At this stage, utilities must build the right foundation that will help them digitalize over a long-term horizon. The following are select initiatives that may be considered:
 - **Digitization of Water Infrastructure:** Begin the deployment of Sensors to enable acquisition of data to ensure real-time, accurate monitoring of water utility across value chain from production to distribution to metering operations. This can be achieved by installation of basic devices such as flow meters, pressure sensors, water quality sensors (pH sensors, turbidity sensors) etc.
 - **Customer Relationship Service:** This can be enabled by installation of systems to support assisted communication channels (SMS, Email, Phone) to streamline basic communications between the utility and its customers, as well as within internal operations, fostering better service delivery. This can help the water utilities optimize billing inquiries, service requests, and capture customer feedback.

- **From Level 2 to Level 3:** A level 2 utility will continue to enhance the physical and digital infrastructure (e.g., upgrading sensors and implementing IoT devices for improved data collection, expanding metering coverage). At this stage, utilities typically focus on automating core processes such as production, distribution, meter operations, billing, payments, and customer service. Initiatives that may be taken at this level to advance to level 3 are:
 - **Management Dashboard:** Design and implement a management dashboard that can provide operational insights to enable data-driven decision making.
 - **Meter Reading App:** Design and implement a Meter Reading Application that will enable automated collection and management of meter readings to ensure greater reading accuracy, reduction in data-entry efforts, and improved meter-to-cash cycle.
 - **NRW Monitoring Tool:** Build an NRW Monitoring Tool to accurately track and report water losses, optimizing water distribution and improving water conservation efforts.
 - **SCADA Systems:** Begin the deployment of Supervisory Control and Data Acquisition (SCADA) systems to automate and enhance the monitoring and control of utility operations, thereby increasing the efficiency and reliability of data collection and operational oversight across value chain of water utility covering production management, distribution and metering operations.
 - **Security and ID Management:** Enhance security, streamline access control, and ensure that data collected is auditable and accountable. This includes functions such as authentication and authorization of employees, managing login credentials, onboarding and offboarding.
 - **Data Platform Foundation (RDBMS, ODS):** Initiate the development of a foundational Data Platform that incorporates Relational Database Management Systems (RDBMS) and Operational Data Stores (ODS) to facilitate data ingestion and storage. This foundation supports essential business intelligence and reporting functionalities, enabling the utility to start organizing and analyzing data for improved decision-making and operational transparency.
 - **Customer Engagement and Complaint Management App:** Develop an app for online bill payment, connection request, grievance redressal, and more with a view to becoming a one-stop shop for customers to interface with the utility in the longer term.
 - **Inventory Management System:** Digitize all paperwork and develop an inventory system for stock movement tracking, automated reordering and supplier management, demand forecasting with capital planning support, and integration with financial systems.

- **Infrastructure Modernization (Network And Comms, Hybrid Cloud Adoption, Scalable, Reliable IT Infrastructure):** Establish foundational digital and IT infrastructure including hybrid cloud, scalable and reliable network and communication systems connecting IT facilities (Data Centers, Disaster Recovery Centers, Cloud Infrastructure, IoT / Edge devices) to facilitate the automated collection and transmission of data.
- **From Level 3 to Level 4:** The focus of utilities at this level should be complete automation of all core functions, enhance support function automation, improve customer and stakeholder engagement through digital channels, and establish a robust centralized data management system. A few initiatives that can help a level 3 utility move forward are:
 - **Data Master Capability:** Develop a framework for managing master data (Customer Master, Asset Master, Inventory Master, and Employee Master), including processes and standards.
 - **Integration Platform:** Establish an integration platform to drive modularity of the tech stack and leverage secure integration technologies.
 - **Field Force Management App:** Establish a central point for all communication between field force and HQ for task allocation, automated scheduling, route optimization, telematics, performance mgmt., hand off management, and other functions to enhance manpower utilization, better job planning, and improved contractor management.
 - **Operational Gain Software:** Implement an operational gain software to optimize electricity and chemical costs by monitoring load factor (of WTPs, reservoirs, tanks), measuring electricity and chemical use efficiency.
 - **GIS Based Infra Planning:** Develop a GIS based tool for asset lifecycle management, maintenance and work order management, infrastructure planning, and maintaining a comprehensive list of geotagged assets to improve inventory planning and maintenance activities.
 - **CRM for Field Force and Metering Operations & Data Mgmt. (MOD):** End to End integration between customers, customer service agents, MODs, and stores including work order management and customer service and support.
 - **Analytics and AI Platform:** Develop an analytics platform with data science tools and self-service sandboxes to leverage the available data for descriptive analytics (e.g., identify water usage patterns, system performance, customer behavior) and performance optimization. Initiate the development of AI/ ML platform capabilities for advanced analytics and AI, AI models, AI operations, and external LLM integration to enable the utility to leverage predictive analytics for improved decision making.
 - **Enterprise Resource Planning:** Develop an ERP tool for financial management, asset lifecycle management, HR management, supply chain and inventory management.
 - **Device Management:** Deploy a comprehensive device management system for managing employee devices (e.g., mobile, laptop, other portable electronic devices) to improve security, enhance work-force efficiency, and optimize device related costs.
- **Level 4 to Level 5:** A utility at level 4 will typically have digitalized all core and support functions within the organization and established robust org-wide data management practices and linkages. At this level, utilities will usually continue to advance the initiatives already undertaken in the previous stage (e.g., improving the AI/ ML capabilities, enhance smart metering infra). To advance to the final level of digitalization, utilities may consider the following initiatives:

- **Partner Vendor Portal:** Enable contractors and partners to interact digitally for purchase order management, contract management, electronic invoicing and payment tracking, performance reporting and compliance monitoring.
 - **AI/ ML and Gen AI Use-Cases:** Elevate existing AI and ML systems to include more complex model integrations, increasing the predictive accuracy by leveraging wider data pool and broadening the scope of automated decision-making capabilities. Develop AI/ ML and Gen AI based forecasting and planning tools
 - **Smart Metering (AMR and AMI):** Adopt Advanced Meter Reading (AMR) or Advanced Metering Infrastructure technologies depending on the business case and overall strategy adopted by the water utility. AMR typically costs lower than AMI since it provides one-way communication capability to transmit the data to automate meter reading and billing, the latter provides advanced capabilities through real-time two-way communication allowing water utilities to closely monitor the consumption patterns.
 - **Customer Relationship Modernization:** Upgrade the customer relationship management systems to incorporate real-time data processing, enhanced customer interaction tools, and integration with other digital platforms to improve customer service and engagement.
 - **Forecasting and Planning tools:** Leverage the centralized Data Platform and AI/ML capabilities to develop a comprehensive forecasting and planning system that integrates various aspects of a water utility's value chain, including production processes, distribution networks, energy consumption, and environmental impact. The project will deliver tools for energy consumption optimization, automated dosing optimization, hydraulic modeling, load forecasting, stormwater management, and climate change adaptation.
- **Level 5 Utilities:** At level 5, utilities become digital leaders that have well established interoperability with key players (e.g., other utilities, weather systems, satellite systems) across the ecosystem and leverage this to advance its strategic objectives. Utilities at this stage can continue to build on the digital capabilities by implementing the following initiatives:
 - **Municipality Level Control Center for Operations:** Central control center for operating and controlling all operating assets of the municipality including Smart Grid Water Network Management DMAs and Sub DMAs, centralized control of all SCADA systems, IoT integration platforms for sensors and devices, and visibility on operations of other utilities in the municipality. This will also include integration with Weather, Satellite, and other 3rd parties and external data sources such as other utilities to enhance predictive maintenance, resource planning, and emergency response strategies.
 - **Disaster and Emergency Response Platform (DERP):** A comprehensive framework designed to enhance the resilience of water utilities against disasters by integrating pre-disaster planning and risk assessment, including the identification of risks to water treatment plants, reservoirs, and other essential infrastructure. The platform may include an Emergency Operations Center for real-time disaster response coordination, a structured approach to damage assessment and restoration, and initiatives for community engagement and staff training to ensure preparedness and effective recovery.

2.6 A Future with AI: Role of AI and Gen AI in Advancing the Growth of Water Utilities

Throughout this chapter, we have explored the digital transformation of water utilities, examining their progression through various levels of digitalization. We touched upon the role of Artificial Intelligence (AI) while discussing the technology architecture, maturity levels, and journey from legacy systems to advanced digitalization. In this section, we will delve deeper into how AI can fundamentally reshape the future of water utilities, **by enabling them to transition from a reactive to a predictive operational paradigm, optimizing responsiveness and efficiency across their systems.**

Artificial Intelligence (AI), bolstered by advancements in Generative AI, is transforming the water utilities sector by significantly enhancing efficiency throughout the entire value chain. AI improves utility systems by analyzing data to predict outcomes, automate processes, and optimize operations, thus boosting both efficiency and precision. Generative AI takes these enhancements further by facilitating content creation, qualitative reasoning, and system orchestration. This allows it to generate models that predict various potential outcomes from given scenarios, thereby enabling utilities to plan more strategically and proactively address potential challenges before they occur.

From sourcing and treatment of water to billing and collection from end customers, AI-driven solutions are enabling smarter management of resources, improving service delivery, and providing critical operational insights.

AI Use Cases Across Water Utility Value Chain

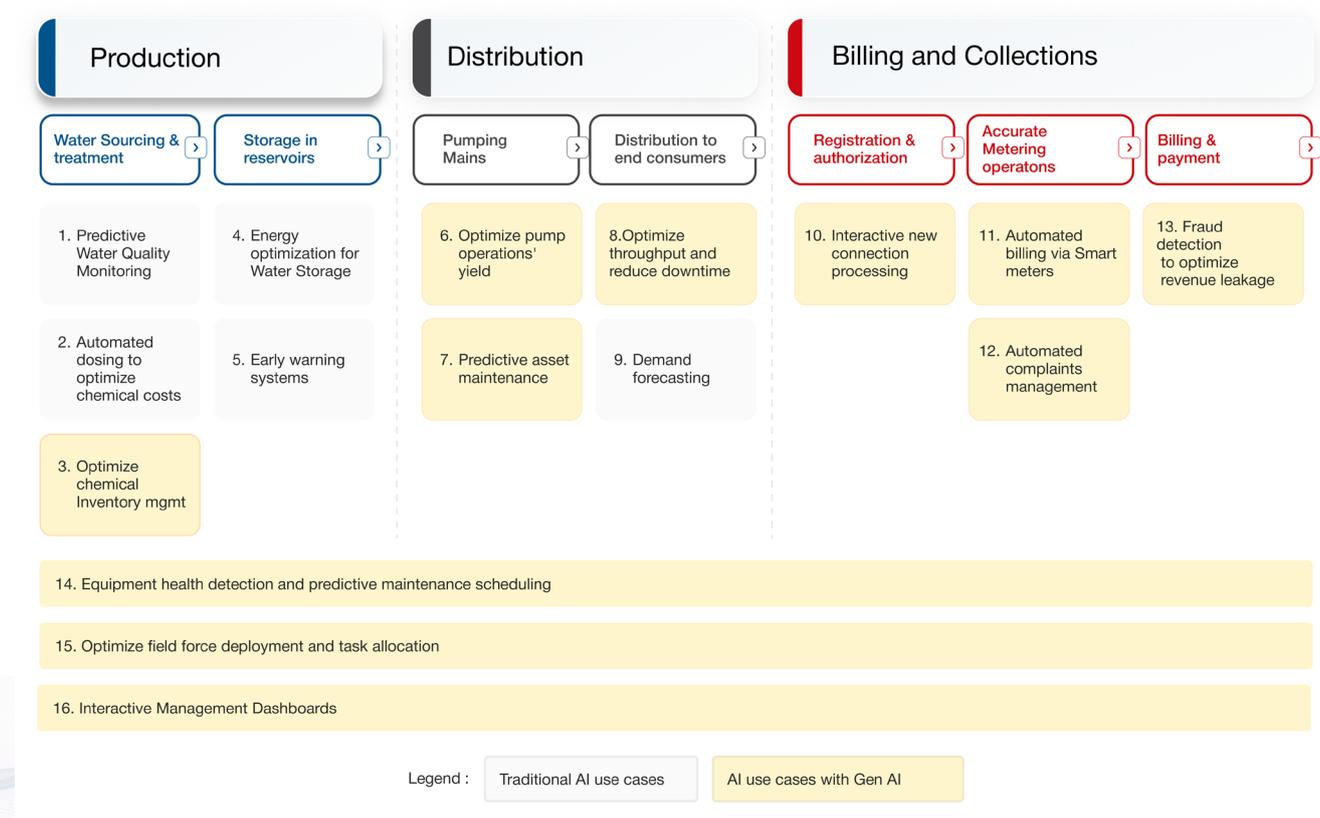


Figure 19: AI use cases across water operations value chain

AI / ML models can improve the efficiency, operating costs and lifespan of the assets used by water utilities. They can drive predictive and prescriptive analytics that can optimize the asset lifespan, perform condition-based monitoring of assets and optimize the asset maintenance schedule, thus optimizing asset maintenance costs and potential revenue leakage. AI can also be used to implement an interactive management reporting and analytics solution leveraging an external LLM platform through a Gen AI agent, that can generate customized reports based on business queries. It can enable long-term planning and data driven decision making across all management support functions.

Once utilities have established a foundational digital infrastructure and have access to high-quality data, they can harness AI to significantly enhance the benefits derived from digitalization. The exhibit in figure 19 above captures potential AI use-cases across the value chain for water utilities.

Leading utilities globally are already implementing AI based solutions in their operations. The table below captures four potential AI based solutions, elucidating the unique value brought in by AI/ Gen AI and real examples of implementation globally:

Brief on Select AI Use Cases Across Water Utility Value Chain

AI Use Case	Description	AI/Gen AI Value Add	Case Studies/Examples
1. Predictive water quality monitoring	Process sensor data, weather data, satellite images etc. and predict water quality parameters (e.g. pH, turbidity)	AI/ML model to predict and raise alerts enabling decisions related to treatment process etc	A Southern European utility achieved a 30% reduction in OPEX by monitoring the water quality and health of critical equipment and chemicals used in treatment processes
4. Energy optimization for Water Storage	Optimize energy consumption in water storage facilities Detect and respond to potential risks at water storage facilities before they become problems	AI/ML models to analyze data from various sensors and SCADA systems to predict pumping schedules based on demand GenAI generates pumping schedules	A Western European municipality achieved a 25% reduction in energy consumption of their large size pumps leading to improvement in system performance through AI enabled energy optimization
7. Predictive asset maintenance for pumping mains and boosting stations	Detect and respond to potential risks at pumping mains and boosting stations before they become problems and save energy consumption.	AI/ML models analyze electrical signals (such as current & voltage) in addition to sensor data (pressure, flow and vibration levels of the pump) to detect anomalies and optimize pump operations and maintenance schedule	A Northern European municipality decreased downtime by 20% for its boosting stations using predictive asset maintenance for pumping mains
13. Smart Metering analytics & fraud detection to plug revenue leakage	Improve billing accuracy, customer satisfaction and optimize revenue leakage by using AI driven smart meter analytics	AI/ML models detect abnormal consumption patterns (using smart meter data) and performs diagnostics analytics to identify potential root cause. GenAI flags anomalies and calls for action	A Central European utility enhanced its revenue assurance and customer satisfaction through AI powered smart metering infrastructure

Sources: BCG, Expert Interviews

Figure 20: Brief on select AI use cases across water operations value chain

As the table above highlights, AI-based Predictive Water Quality Monitoring is a high-potential use-case of AI for water utilities. By deploying IoT sensors across the water treatment systems, utilities can gather real-time data that can be fed to AI models to analyze water quality instantaneously using advanced algorithms. This setup allows for the early detection of potential issues and integrates findings into dashboards that facilitate proactive management and immediate adjustments. Furthermore, Generative AI enhances these systems by improving predictive accuracy and automating decision-making processes. It simulates various scenarios to guide resource allocation and emergency planning effectively. This AI based solution not only helps foresee problems but also proposes optimized solutions continuously, boosting efficiency, ensuring water quality, and advancing sustainability within utility operations.

AI Based Predictive Water Quality Monitoring Journey

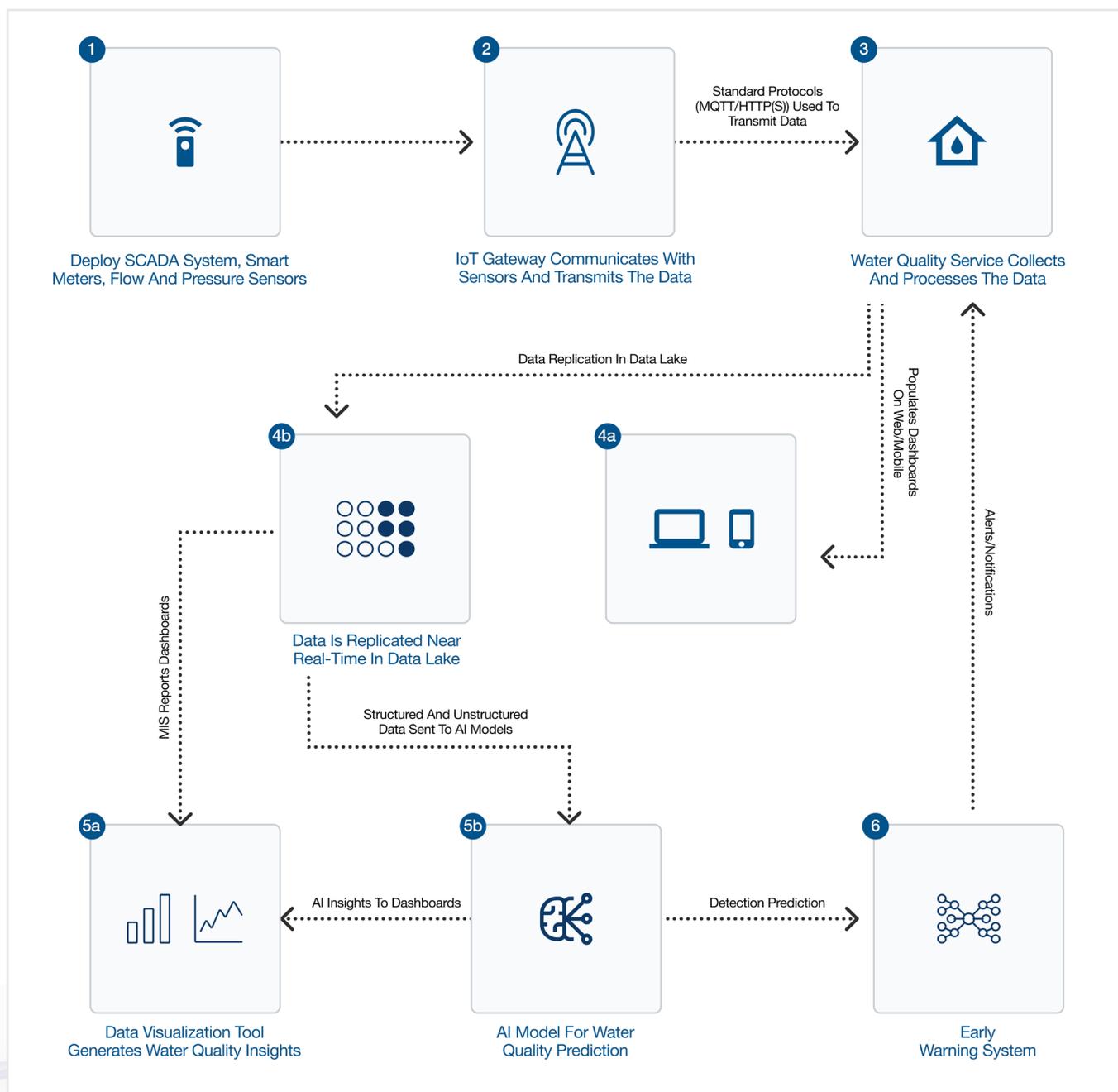


Figure 21: AI Based Predictive Water Quality Monitoring Journey

The journey towards digital transformation with AI at the helm will undoubtedly play a crucial role in shaping the future of global water management, making it **more adaptive, resilient, and sustainable**. However, the success of Artificial Intelligence (AI) models depends on **several key factors that influence their accuracy and efficiency**.

Factors that will influence the accuracy and efficiency of AI powered solutions are:

- 1. Quality and Availability of Data:** AI models require large diverse datasets to improve accuracy. The data must be clean, labelled, and standardized.
- 2. Model Design and Algorithm Selection:** It is important to choose the right AI technique (e.g., Machine Learning, Deep Learning, Natural Language Processing) to find the right balance between performance and complexity. Hyperparameter tuning helps in improving the accuracy further.
- 3. Model Training and Validation:** Model training process takes time as it involves multiple techniques (e.g., supervised learning, unsupervised learning, reinforcement learning) leveraging the right technologies (e.g., AutoML). The choice depends on data availability, computational resources, and business requirements.
- 4. Monitoring and Continuous Improvement:** AI models need to be monitored continuously to identify drift in data patterns that may require retraining of models to improve accuracy over time.

As the water sector navigates an era marked by rapid technological advances, a race to harness AI is poised to reshape the future of how water utilities operate. **AI promises to be a pivotal force that can revolutionize water management through enhanced efficiency, smarter resource allocation, and predictive operational insights.** To conclude this chapter, we explore two case studies that highlight AI's potential in water utilities, demonstrating how it enables the use of data to develop impactful solutions:

Case Study 2A: AI-Based Leakage Risk Assessment Solution

Overview

A Japanese startup²⁸ specializing in geospatial analytics and AI has developed an innovative solution for water utilities aimed at **improving leakage detection and infrastructure management**. The solution provides a **leakage risk assessment and management platform** based on the company's proprietary **AI-powered land evaluation engine**.

This platform **aggregates smart data from diverse sources**, including satellite imagery, to identify areas with a high risk of water leakage within a **100-meter spatial radius**. By leveraging advanced **AI and satellite Data Analytics**, it enables proactive monitoring and decision-making.

Water utilities can **share their GIS asset data** with the platform, and in return, receive a **comprehensive analysis of leakage risks** across their distribution networks. This enables them to **optimize maintenance schedules** and allocate resources more efficiently, ultimately reducing water loss and operational costs.

Data Sources Used and Process

The solution combines data from water utilities (water network, pumps, valves, sensors) with SAR data to produce imagery which helps in predicting leakage location, deterioration and assessing leakage risk. The GIS data provides the spatial coordinates of the water utility assets to the AI/ML model. This data is correlated with various data sets such as satellite images, weather and environment data at those coordinates to predict the risk of leakage in the distribution assets (pipes, valves, pumps) in that region.

Digital Architecture Prerequisites for Installation

- A Geographic Information System (GIS) is a critical technology that can enable water utilities to share the spatial data related to all the assets in the distribution network such as pipes, valves, hydrants etc.
- Third party integration framework to share the GIS data (selected asset information) with the external agencies or third parties.
- A Data Platform including a data ingestion service to consume the data from third-party agencies and a visualization tool to visually augment the information for consumption by decision makers.

²⁸Company Website, Expert Interviews, Secondary Research

Benefits

Expected benefits of this solution include up to 65% reduction in inspection costs and up to 85% reduction in the investigation period through projects with local authorities conducted in FY2022 with the Japanese Cabinet Office.

Case Study 2B: AI-Based Pipeline Deterioration Diagnosis Solution

Overview

A Japanese startup²⁹ focused on AI-driven infrastructure diagnostics offers a platform that delivers **predictive and prescriptive insights** for the maintenance of water distribution assets. This solution is built around an **AI-based pipeline deterioration diagnosis system**, which leverages **machine learning algorithms** to forecast asset degradation.

By integrating **environmental factors with water pipeline data**, the platform generates **predictive insights on pipeline deterioration and replacement needs**. This enables water utilities to make **data-informed decisions** regarding asset maintenance, prioritize replacements, and extend the lifecycle of critical infrastructure.

Data Sources Used and Process

The health of pipelines is diagnosed by utilizing pipeline data (from a water utility's GIS system and Asset Management System) and various environmental information surrounding the pipelines. Pipeline data and past leak history is retrieved from the waterworks bureau. This data is then fed into AI/ML algorithms which predict distribution asset health along with probability of leakage, damage etc. This information can enable the water utilities to optimize the maintenance and replacement schedule of the distribution assets.

Digital Architecture Prerequisites for Installation

- A Geographic Information System (GIS) is a critical technology that can enable water utilities to share the spatial data related to all the assets in the distribution network such as pipes, valves, hydrants etc.
- An Asset Management System with centralized record of all assets their make, manufacture, asset maintenance schedule, replacement schedule etc.

²⁹Company Website, Expert Interviews, Secondary Research

- Third party integration framework to share the GIS data (selected asset information) with the external agencies or third parties.
- A Data Platform including a data ingestion service to consume the data from the third-party agencies and a visualization tool to visually augment the information for consumption by decision makers.
- An external LLM based Gen AI agent can consume the predictive insights and generate optimized maintenance and replace schedule which can be consumed by the Asset Management System to optimize the end-to-end asset lifecycle management.

Benefits

- Optimized distribution asset maintenance cost.
- Prevent revenue leakage due to pipeline damages.

Chapter 03

Value from Digitalization – What Digital Can Bring for Utilities and Communities



In the previous chapter, we looked at the business pain points and major KPIs of water utilities that can be addressed by digitalization. We also examined what digital transformation entails, the ideal end-state digital architecture, the different levels of digital maturity, and the strategic initiatives utilities can implement to advance their digital capabilities.

In this chapter, we extend our focus to the **tangible benefits of digitalization – not only for water utilities but also for broader socioeconomic development**. For water utilities, we examine the benefits of digitalization for each part of the value chain. For socio-economic benefits, we look at the role of digitalization in advancing the achievement of Sustainable Development Goals (SDGs)³⁰. We will also examine the **potential for innovation emerging from digitalization initiatives of** water utilities.

3.1 Digital Dividends: The Promise of Digitalization for Utilities

3.1.1 How Digitalization Can Drive Optimization Throughout the Value Chain

While broad-based adoption of digitalization in water utilities is still underway, tangible financial benefits of digitalization have already started to accrue in comparable industries - organizations in the Power, Utilities and Renewables sector with strong Digital and AI capabilities reported a **1.3x EBIT³¹ uplift** compared to industry peers, directly attributed to their digital and AI advancements³².

Digitalization has proved valuable to water utilities that have been its early adopters, with tangible financial benefits accruing from the operational efficiencies it helps to drive. For example, an **Asia Pacific based utility saved over USD 2.5 million³³ through real time monitoring of system flows.**

In Section 2.1 of this report, we looked at the major KPIs and business pain points for Water Utilities across the value chain, from Assets and Investments to Management/ Support Functions. We also highlighted the KPIs and pain points that could be directly addressed through digitalization. In this chapter, we will look at how digitalization influences these KPIs and pain points, exploring the value creation possible through digitalization at each part of the value chain and highlighting examples of potential tools that could be used. Please note that the tools mentioned in the table below (e.g., GE iFIX, Xylem YSI) are examples for purposes of illustration and should not be considered as recommendations.

³⁰SDGs as declared by the United Nations <https://www.undp.org/sustainable-development-goals>

³¹EBIT (Earnings Before Interest and Taxes) is a financial metric that measures a company's operating profitability by calculating revenue minus operating expenses, excluding interest and tax expenses.

³²BCG research

³³:[Annual Water Conservation Report 2023-24](#)

	Key Pain Points	Benefits of Digitalization ³⁴	KPIs
Assets & Investments	<ul style="list-style-type: none"> • Inefficient investment and expansion • Inefficient maintenance planning 	<ul style="list-style-type: none"> • Strategic guidance for infrastructure expansion and investments can be provided by leveraging digital tools (e.g. GIS based Infrastructure planning tools like EsriArcGIS, QGIS). These tools facilitate comprehensive, data-driven planning and capex prioritization, while incorporating demand forecasts, demographic variables (e.g. population growth, urbanization, per capita increase etc.), and environmental factors. • Reduction in downtime and emergency repair costs is attributable to continuous asset monitoring and early prediction of equipment failures which are supported by advanced analytics, AI and IoT 	<ul style="list-style-type: none"> • Operational downtime rate • Asset utilization rate • Mean time between failures
Production	<ul style="list-style-type: none"> • Inefficient treatment processes • Contamination and poor quality of intake water • High and irregular energy consumption • High NRW attributable leakage 	<ul style="list-style-type: none"> • Real-time monitoring of intake water quality metrics, to ensure water input reliability for treatment processes, can be done using SCADA systems (e.g. SIEMENS SIMATIC WinCC, GE iFIX) and IoT sensors (e.g. Xylem YSI, SIEMENS SITRANS) which track flow rates, pH levels, turbidity, and contamination risks • Performance optimization and reduction in energy consumption of water treatment plant and pumping systems can be achieved by using Programmable logic controllers (e.g. PLCs like Rockwell ControlLogix, Honeywell ControlEdge) • In electric motors, optimized use of energy and reduction in consumption can be achieved by controlling the motor speed using Variable Frequency Drives (e.g. VFDs like SIEMENS SINAMICS, Rockwell PowerFlex) 	<ul style="list-style-type: none"> • Water quality standard compliance rate • Cost per unit water treated • Energy efficiency ratio

³⁴Source: JICA and BCG research/ case experience

	Key Pain Points	Benefits of Digitalization	KPIs
Distribution	<ul style="list-style-type: none"> Loss of treated water due to pipeline issues/ breakdowns High and irregular energy consumption Water theft 	<ul style="list-style-type: none"> Significant reduction in NRW, more equitable distribution of water and identification of areas needing infrastructure improvements result from embedding technologies such as Digital Twin (e.g. Bentley OpenFlows WaterSight, SIEMENS SIWA), Geographic Information Systems (GIS), and automated control of valves and pumps. These technologies localize leak detection, enable real-time water flow monitoring and pressure management Water utility engineers can design, operate, and manage their systems more efficiently by incorporating Hydraulic Modeling Systems (e.g. Bentley WaterGEMS, EPANET) – these systems analyze the behavior of water distribution systems, wastewater collection systems, and stormwater drainage systems 	<ul style="list-style-type: none"> Water loss percentage Average service hours per day Energy efficiency ratio
Collections & Customer Support	<ul style="list-style-type: none"> Inaccurate bill generation Unreliable customer data and unauthorized connections Unresolved customer concerns and long response time High meter failures 	<ul style="list-style-type: none"> Improved accuracy and anomaly detection (such as leaks, unauthorized use) are some of the benefits realized by the OCR-based handheld/real-time and precise billing facilitated by smart meters The data generated can run various use cases (such as category mismatch, fictitious billing, estimation-based billing) to sustainably improve database and provide consumption-based bills Higher customer engagement, satisfaction, and reduced costs associated with manual billing are the benefits associated with digital platforms with interactive portals provide where customers can manage their accounts, track water usage, and handle payments and service requests online at their convenience 	<ul style="list-style-type: none"> Metering efficiency Collections and billing efficiency Customer satisfaction index

	Key Pain Points	Benefits of Digitalization	KPIs
Mgmt./ Support Functions	<ul style="list-style-type: none"> Low workforce productivity 	<ul style="list-style-type: none"> Efficiency gains is the key benefit realized from field force management – underpinned by better scheduling and real-time monitoring Centralized and streamlined management of support functions such as finance, human resources, procurement, vendor partnerships, and regulatory compliance is the key benefit of modernizing the Enterprise Resource Planning (ERP) layer. E.g. SAP S4/HANA, ORACLE ERP 	<ul style="list-style-type: none"> Staff per 1000 connections

Utilities worldwide are currently harnessing the transformative power of digitalization. From initiating quick-win projects with minimal prerequisites, to deploying extensive, organization-wide digital strategies that leverage advanced technologies, digitalization offers substantial benefits at every stage of utility maturity. **Following are a few examples of tangible benefits that water utilities have realized as a result of digitalization initiatives:**

Utilities Worldwide Have Already Realised Significant Gains Across the Value Chain from Digital Transformation

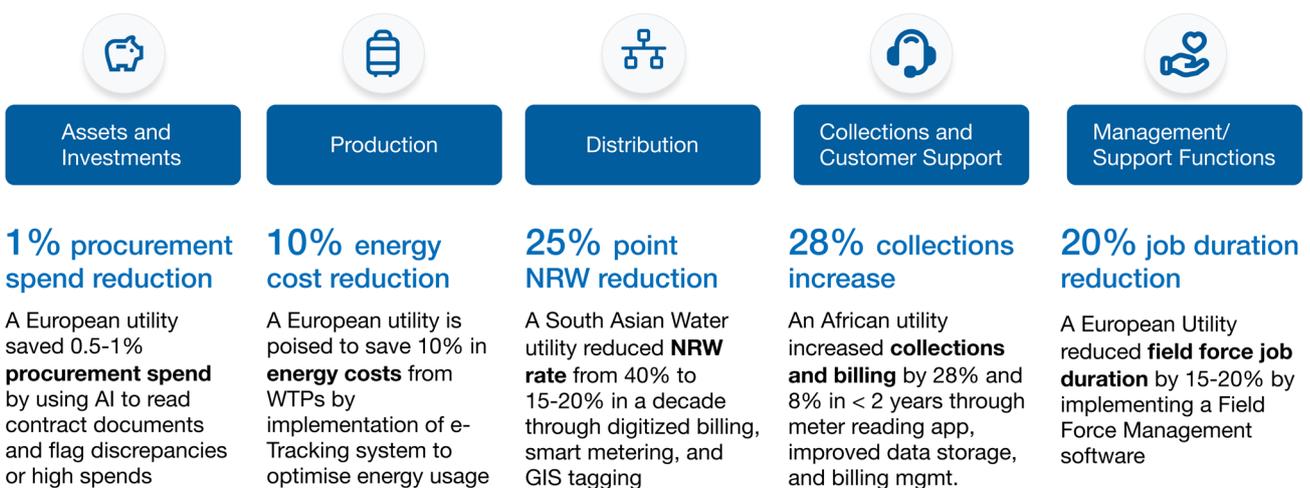


Figure 22: Value creation from digitalization for Water Utilities³⁵

³⁵Source: JICA and BCG Research/Case experience, Annual Report of Utilities, Reports from Development Partners, Expert Interviews, Press Research

3.1.2 Enhancing Construction Management and Operations Through Digital and Data

In emerging markets, the construction of large-scale water infrastructure projects, such as water treatment plants, offers significant opportunities for efficiency gains and improved project execution through digital transformation. By leveraging advanced digital solutions, utilities can enhance project management, reduce delays, and optimize costs. Key enhancements include:

- 1. Structured Project Management:** Scheduling tools (e.g., Primavera P6, MS Project) enable scheduling, resource allocation, and progress tracking, reducing delays and cost overruns.
- 2. Project Governance:** Digital tools (e.g., Oracle Aconex) streamline RFIs, compliance tracking, contract management, and decision-making workflows, ensuring transparency and accountability.
- 3. Workforce Optimization:** AI-driven tools (e.g., Anaplan, Infor) help forecast labor demand, adjust hiring plans, and prevent workforce shortages.
- 4. Procurement and Supply Chain Efficiency:** Digital procurement tools (e.g., Coupa Procurement, SAP Ariba) improve inventory tracking, supplier selection, and demand forecasting, preventing material shortages and project delays.
- 5. Engineering Design and Feasibility:** Advanced modeling tools (e.g., Bentley OpenFlows, Autodesk InfraWorks) enable hydraulic simulations, site assessments, and optimized infrastructure layouts, reducing design errors.
- 6. Real-Time Monitoring and Predictive Insights:** IoT sensors and digital site monitoring tools provide real-time tracking of construction progress and asset performance, enabling proactive issue resolution.

EPC contractors and Project Management Consultants (PMCs) typically implement these solutions, but utilities should develop a working knowledge of these tools to ensure better oversight, accurate progress evaluation, and informed decision-making. While digital tools significantly enhance efficiency, utilities must still proactively manage regulatory approvals, permits, and governance procedures to prevent bottlenecks.

Data captured during the construction of capital assets is essential for the long-term operations and maintenance (O&M) of utilities, enabling better asset health management, performance tracking, and lifecycle cost optimization. For instance, asset specifications and equipment data can be collected through RFID, QR codes, and IoT tracking, stored in ERP, EAM, or GIS databases, and used for maintenance planning, lifecycle tracking, and asset optimization. As such, it is important for utilities to define data requirements upfront in contracts, specifying what information to capture, in what format, and how it integrates with existing systems. However, in emerging markets, poor handover processes, lack of digital tools, and vague contractual requirements often lead to data loss, inefficient maintenance, and higher lifecycle costs. When captured, stored, and used effectively, this data strengthens asset resilience, enhances service reliability, and ensures long-term operational efficiency. For more information on the role of digital and data in enhancing construction management and supporting O&M of assets, please refer to Appendix C.

3.2 A Ripple Effect: Addressing Socio-Economic Challenges and Driving Innovation Through Water Utility Digitalization

3.2.1 Digitalization's Influence on Socio-Economic Challenges

Water plays a pivotal role in and has far reaching influence on socioeconomic development. The benefits of digitalization extend beyond the utilities to encompass the broader socio-economic landscape and aid the progress towards achieving UN SDGs. Moreover, access to clean water is strongly linked to public health, gender equity, child education, and social stability overall the progress towards achieving UN SDGs. Moreover, access to clean water is strongly linked to public health, gender equity, child education, and social stability overall.

The World Wildlife Fund (WWF) estimates the annual economic value from direct consumption³⁶ of water by municipalities alone could be almost USD 1.5 trillion.

Water availability, accessibility, and quality are deeply intertwined with human well-being, economic advancement, and environmental sustainability. Effective management and equitable distribution of water resources are essential for nurturing healthy communities, stimulating economic growth, and maintaining sustainable ecosystems. Ensuring access to clean and abundant water is therefore a critical challenge, one that can catalyze significant improvements in global health, enhance educational and economic opportunities, and strengthen resilience against environmental fluctuations and crises.

Digitalizing water utilities requires upfront investment (which we will discuss in greater detail in 4.4) but promises significant returns if implemented correctly, considering the profound socioeconomic implications of such interventions. The exhibit below summarizes how water utilities influence various key socioeconomic factors linked to the UN's sustainable development goals:

³⁶Source: World Wildlife Fund. The figure only includes Direct Consumptive Use includes usage of water by municipalities. The figure does not include Non-Consumptive Use (e.g., hydropower, fisheries), Direct Consumptive Use by industries and agriculture, as well as indirect value captured from biodiversity promotion, disaster risk protection, climate change etc.

Critical Socio-Economic Factors Influenced by Water Utilities Linked to UN's Sustainable Development Goals (SDGs)



Sources: United Nations, UNICEF, World Economic Forum, World Bank, Water.Org, Water UK, JICA, BCG case experience

Figure 23: Critical Socioeconomic Factors Influenced by Water Utilities³⁷

Good Health and Well-being (SDG 3)

Access to safe and reliable water is directly linked to health, education, and quality of life. When water systems fail, communities face increased disease burdens, gender inequality, and reduced economic mobility. Digital transformation of utilities enables real-time water quality monitoring, automated leak

³⁷Sources: United Nations, UNICEF, World Economic Forum, World Bank, Water.Org, Water UK, JICA and BCG Research/Case experience

detection thus ensuring consistent access to clean water. This enhances public health, reduces social disparities, and improves overall well-being, especially for vulnerable populations.

Clean Water and Sanitation (SDG 6)

- **Water Loss:** In emerging market economies, roughly 45 million³⁸ cubic meters of water are lost daily with an economic value of over USD 3 billion per year. Saving half of those losses would provide enough water to serve at least 90 million people. Digitalization would help improve asset management, leak detection, demand forecasting, enabling utilities to reduce water losses directly impacting water quality and water use efficiency.
- **Water Scarcity:** With 2 billion people living in water-scarce regions³⁹, innovative water treatment solutions are essential to improving water availability and reuse. A leading Indian startup⁴⁰ was able to treat over 750 million liters of water for reuse, using zero chemicals, having 95% water recovery rate at a 75% lower carbon footprint using electrically driven decentralized wastewater treatment solutions.

Gender Equality (SDG 5)

Women and girls spend 200 million⁴¹ hours daily collecting water, which limits their participation in the workforce and formal schooling respectively. Digital technologies can empower utilities and municipal authorities to optimize water availability and ensure more equitable distribution. By enabling data-driven infrastructure planning, predictive maintenance, and automated water scheduling, digital solutions help reduce supply disruptions and improve local access to safe water. This, in turn, minimizes the time women and girls spend on water collection, allowing them to pursue education, participate in the workforce, and engage in broader economic and social activities.

Zero Hunger (SDG 2)

Good nutrition is essential for healthy growth and development of children and is a core part of SDG 2. Contaminated water can lead to waterborne diseases that cause malnutrition by impairing nutrient absorption. Digitalization of water utilities enhances nutrition by ensuring a safe and reliable water supply for drinking, food preparation, and sanitation. Real-time water quality monitoring and predictive maintenance prevent contamination, reducing the risk of illnesses like diarrhea that contribute to stunting and wasting in children. By safeguarding water quality, digitalized utilities help protect nutrition, especially for vulnerable populations.

Sustainable Cities and Communities (SDG 11)

Water deficits are linked to 10 percent of the increase in total migration globally between 1970 and 2000.

By the end of this century, worsening droughts are projected to affect about 700 million people with more than 85 percent of people affected living in low- or middle-income countries⁴².

³⁸World Bank . Retrieved from: <https://www.worldbank.org/en/news/press-release/2016/09/01/the-world-bank-and-the-international-water-association-to-establish-a-partnership-to-reduce-water-losses>. ³⁹UNICEF. Retrieved from: [Water scarcity | UNICEF](#). ⁴⁰Source: World Economic Forum; [These 10 start-ups are securing the world's freshwater | World Economic Forum](#). ⁴¹Water.Org. Retrieved from: [The Water Crisis: Shortage, Problems & Solutions | Water.Org](#). ⁴²World Bank. Retrieved from [Lack of Water Linked to 10 Percent of the Rise in Global Migration](#).

Yet it is often the poor who cannot afford to leave - residents of poor countries are four times less likely to move than residents of wealthier countries. Digital technologies can analyze drought patterns - AI can be used to predict long-term drought risks, advanced analytics to analyze historical climate data, current water levels, satellite imagery and remote monitoring of rainfall patterns and soil moisture depletion. Additionally, water accessibility can be improved to drought-prone regions by using smart leak detection technologies.

Climate Action (SDG 13)

Action in improving water management is critical to environmental sustainability, as it would influence carbon and GHG emissions, climate resilience, and conservation of critical resources.

Water utilities account for 2% of GHG emissions⁴³ – equivalent of the global shipping industry – due to energy intensive processes for water sourcing, treatment, and distribution. However, digitalization offers a path to significant emissions reduction

As climate change intensifies, digital transformation in water management has emerged as a critical enabler of sustainability in-turn helping in carbon footprint reduction and mitigating climate change aftermaths:

- **Reduced Carbon Footprint:** By leveraging AI-driven energy optimization and smart monitoring systems, utilities can detect inefficiencies, optimize pump operations, and reduce energy waste. For example, A European utility⁴⁴ reduced energy consumption in its pumping mains by 60% by deploying a smart pumping solution; additionally, remote monitoring provided the utility with real-time visibility and control across the pumping network which reduced its annual carbon output by 160 tCOe. As more utilities integrate AI-powered analytics and IoT-based monitoring, the sector can make substantial progress toward decarbonization, reducing operational costs while enhancing sustainability.
- **Climate Change:** 80% of climate change impacts⁴⁵ are felt through water, manifesting as droughts, floods, rising sea levels, and extreme weather events that disrupt communities, agriculture, and industries. Digital transformation in water management such as through AI-powered early disaster warning systems can help utilities anticipate and mitigate flood/ extreme weather event risks, while smart water grids optimize storage and distribution to prepare for droughts. IoT-enabled monitoring networks track groundwater levels, precipitation patterns, and water quality in real time, allowing for proactive decision-making.

Decent Work and Economic Growth (SDG 8)

Water is the invisible force behind economic productivity—powering industries, sustaining agriculture, and fueling urban expansion. However, inefficiencies in water utilities - marked by high water losses, poor demand planning, and outdated infrastructure - often disrupt economic activity. As digitalization strives to solve for these inefficiencies, it bolsters economic growth via employment creation and improves productivity by saving time in process disruptions and ensuring workforce wellness:

⁴³Source: Water UK; retrieved from: [World Water Day 2021: Global water community challenged to join the Race to Zero | Water UK](#).

⁴⁴Secondary research.

⁴⁵Sustainable Development Goals Summit, United Nations. [Water for Climate, Resilience, and Environment](#)

- **Creation of Employment:** Digitalization of water utilities not only improves efficiency but also creates new job opportunities across multiple sectors. As utilities adopt digital technologies, they require skilled professionals in fields such as Data Analytics and IoT system maintenance. This shift also stimulates employment beyond utilities, supporting job growth in technology development, smart infrastructure deployment, and digital service support. Studies in the United States show that every USD 1 million⁴⁶ invested in the country's traditional water supply and treatment infrastructure generates between 10 and 20 additional direct jobs and a further 3.86 indirect jobs created against each direct job. In emerging markets, this job creation impact is like to be higher due to greater infrastructure gap and labor availability
- **Productivity Gains:** Reliable water access is essential for economic productivity, reducing time lost to water collection, illness, and disruptions in industrial and agricultural activities. According to the WHO⁴⁷, investments in drinking water and sanitation have a benefit-to-cost ratio (BCR) of up to 5:1, with even higher returns in regions like South Asia and Central Africa due to significant time savings and reductions in waterborne diseases.

3.2.2 Innovation Potential Unlocked by Digitalization of Water Utilities

Improved digital infrastructure and data availability can spur significant innovation in the water management space. Water Solutions was ranked number 1 by Morgan Stanley⁴⁸ in investor interest for ESG investors due to high innovation potential in 2024.

The digitalization of water utilities represents a paradigm shift, unlocking unprecedented opportunities for innovation in infrastructure management, service delivery, and sustainability. At its core, digital transformation enables a shift from reactive to proactive and predictive water management, fostering greater efficiency, resilience, and adaptability. By harnessing data as a strategic asset, water utilities can transition from siloed, static operations to dynamic, interconnected ecosystems where decision-making is guided by real-time insights and long-term predictive modeling.

Digitalization also redefines value creation in the sector, integrating advanced analytics, automation, and AI-driven optimization to enhance not only operational performance but also customer engagement and regulatory compliance. For example, smart home innovations are emerging on the consumers' end, that integrate with residential water meters, providing personalized conservation insights, automating water-saving actions, and optimizing appliance usage. These solutions can automatically shut off IoT-enabled devices when not needed, preventing wastage and driving more efficient, sustainable water consumption. Moreover, it enables the emergence of new business models, such as demand-responsive pricing, decentralized water treatment networks, and integrated resource management. By aligning digital technologies with sustainability goals, water utilities can transform from mere service providers into innovation hubs that contribute to broader environmental and societal resilience. Ultimately, the digitalization of water utilities is not just about technological advancement—it is about reimagining the way water is managed, delivered, and valued in a data-driven world.

Below are select case studies of private and public sector organizations that are undertaking novel innovation either as part of digitalization programs for water utilities, or using the processes and data emerging from digitalization to drive innovation:

⁴⁶United Nations. Retrieved from: [Water drives job creation and economic growth, says new UN World Water Development Report | UN-Water](#)

⁴⁷World Health Organization - [Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage](#). ⁴⁸Morgan Stanley. Retrieved from: [MSInstituteForSustainableInvesting-SustainableSignals-Individuals-2024.pdf](#)

Case Study 3A: Smart City IoT Platform By an Indian Public Sector Company

Overview

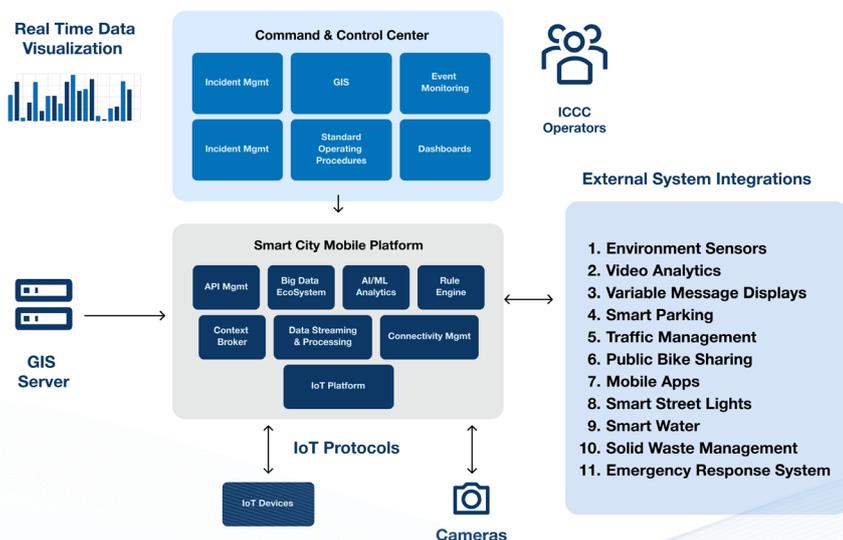
An Indian public sector company has developed a proprietary Smart City Integrated Command and Control Center (ICCC) Platform, which provides a centralized smart city-wide Command and Control Center with the capability to integrate IoT sensor data centrally; the platform is enabled with analytics and produces a Common Operating Picture as single version of truth. **Smart Water Integration is one of the several system integrations included as part of the ICCC platform.**

Key Platform Capabilities

- The platform is cloud deployable, secure, scalable and resilient that enables development of smart city applications. Key platform capabilities include:
- Based on core principles of open source and open standards to build IoT Platform.
- Leverages the Big Data ecosystem, analytics, data Insights and AI-ML engines
- Connectivity to different city sources using APIs and other connectivity mechanisms for data extraction and transformation.
- Web based ICCC portal with visualization dashboards – KPIs, incident orchestrations and situational awareness.

Platform Mechanism

- An exhibit of the working mechanism of the ICCC platform is shown below with the external integrations that it can support:



Case Study 3B: Water Point Data Exchange

Overview

The Water Point Data Exchange (WPdx)⁴⁹ is a global platform designed to enhance rural water access by facilitating the sharing and utilization of water point data. It aggregates information from various sources, including governments, non-governmental organizations (NGOs), and researchers, to create a comprehensive, harmonized dataset of water points worldwide (Global Data Repository). This data is used by decision support tools to carry out advanced GIS and ML analysis on the fly to provide concrete insights, such as which water point to send a technician to rehabilitate next to reach the most people.

Mechanism

The approach of WPdx is highlighted in the exhibit below:

- **Step 1**
Governments and their partners are already collecting substantial amounts of data. However, data is often too fragmented to use, with different approaches for data collection and storage. Given the challenges in accessing and using data, it is typically only used for reporting and not decision support.
- **Step 2**
All stakeholders can easily use the WPdx Data Standard to harmonize their existing data structure. Formatting existing data into the WPdx Data Standard typically takes less than 30 minutes. The WPdx Data Standard fits most water point data, even if it was collected with no knowledge of the standard.
- **Step 3**
After formatting, the file can be uploaded and published to the WPdx Global Data Repository. The WPdx ingestion engine removes duplicate entries, links multiple updates to the same water point, and integrates the data into the Global Data Repository to provide easy access to data. All data is now harmonized and integrated.
- **Step 4**
Decision support tools access data from the Global Data Repository and automatically carry out advanced GIS and machine learning analysis on the fly. Designed in partnership with governments and data scientists, these tools provide concrete insights, like which water point to send a technician to rehabilitate next to reach the most people.

⁴⁹Water Point Data Exchange - <https://www.waterpointdata.org/>

Chapter 04

Successful Execution of Digitalization – How Utilities Can Navigate the Path to Digital Transformation



In Chapter 3, we explored the impact of digital transformation across the utility value chain, highlighting both operational efficiencies and broader socio-economic benefits aligned with the UN Sustainable Development Goals (SDGs).

This chapter focuses on the **successful execution of digitalization** for water utilities. We begin with **two case studies** – one featuring a South Asian utility in the early stages of digital transformation, and another showcasing a European city that successfully reduced water losses, improved customer engagement, and reduced emissions through a well-executed digital transformation. We will then outline **the steps to operationalizing digital transformation**, highlight the **Key Success Factors (KSFs)** that enhance success rates and help utilities **avoid common pitfalls**, and introduce a **prioritization and phasing framework** to support the development of an implementation roadmap. To illustrate these success factors in action, we will take a closer look at the first case study, examining how the South Asian utility is applying them in practice. Additionally, we will provide **cost estimates for digital initiatives**, offering utilities and development partners a clearer understanding of the investment requirements for digital transformation.

Case Study 4A: How a South Asian Utility Initiated its Multi-Year Digital Transformation Journey⁵⁰

Context

As the 2nd largest water utility of the country, this utility serves approximately two million consumers, with over 90,000 connections across a 1,000 km-long water distribution network, producing approximately 500 million liters per day (MLD).

The utility was facing several challenges in terms of its performance across KPIs. Some of the major challenges are highlighted below:

- **60%+ accounts receivables as a % of revenue** compared to good practice of 5-10% due to delays in bill generation and distribution as well as difficulties in payment collection, error detection, and reporting. This contributed to an **annual loss of USD 10 Million. and a negative Net Income Margin of ~50%** due to low collection efficiency and high levels of water losses⁵¹.
- **Reliance on manual reporting and fragmented data sources, limiting real-time monitoring of billing, collections, and network performance.** As such, decision-making was reactive rather than proactive, affecting overall service delivery and financial performance.

⁵⁰JICA and BCG research/case experience.

⁵¹Utility Annual Report

- **30%+ NRW %, significantly higher than the 5-10% range typically seen in financially sustainable utilities** due to manual water loss detection, reactive pressure monitoring, interventions based on manual reporting, and limited end to end visibility of value chain.

Over the past few years, the utility had taken initial steps to implement foundational IT systems to enhance service delivery and operational efficiency. However, it was still at an early stage of digitalization (Level 2) having only its core billing system digitalized and SCADA to monitor production and 50% of distribution.

Digital Transformation Journey and Interventions Taken

Given the challenges outlined above, a clear need for digitalization emerged, prompting the utility to embark on a comprehensive and long-term digital transformation journey in early 2024. To support this effort, the utility partnered with a leading development partner, which in turn engaged a prominent consulting firm to assist in the design and execution of its digital strategy. Overall, the utility prioritized 27 digital initiatives to enhance its capabilities, including three quick wins for immediate execution to drive early results.

The three Quick Win initiatives implemented were as follows:

- **Meter Reading App:** To fully digitize the meter-to-cash process, replacing manual, paper-based workflows with an integrated digital system. Previously, manual interventions at every stage led to inefficiencies and delays. The MRA enables real-time data capture, automated billing integration, and transparent payment options for customers. An MRA Admin Portal was also developed, allowing revenue officers and supervisors to manage users, monitor billing, and resolve issues efficiently.
- **Management Dashboard:** Designed for the revenue team to track billing, collections, and arrears in a centralized platform. Previously, data was scattered across systems, requiring manual consolidation for analysis. The dashboard streamlines operations, providing a user-friendly interface for real-time tracking, pattern identification, and data export, ensuring efficient financial performance monitoring and optimized cash flow management.
- **NRW Monitoring Tool:** To centralize data from SCADA, billing systems, and databases for monitoring water inputs, outputs, and losses across the distribution network. This tool provides actionable insights, enabling teams to proactively manage water losses, optimize resources, and ensure equitable distribution. Previously, NRW management was reactive and fragmented, relying on manual data aggregation and ad hoc interventions.

Outcome

The following outcomes have been realized from the quick wins that have been implemented and have been in operation for three months as of this writing:

- **Meter Reading App:** Recurring incrementation revenue potential of USD 0.45 million. due to identification of unregistered deep tube wells, improved input accuracy from 53% to 98%, and increased defective meter identification from 24% to 34%.

- **Management Dashboard:** Consumption analysis helped identify ~10% of underbilled/ undersupplied consumers, accounting for ~ USD 1 million. in annual revenue loss and consumers with high consumption with a potential revenue loss of USD 1 – 2.5 Million.
- **NRW Monitoring Tool:** Helped identify district-metered areas with high (>40%) NRW rates for prompt actions and 50+ interconnections at the city level. It is estimated that the utility will be able to save ~USD 1 million. per within the first full year of implementation.

Case Study 4B: How a European City Leveraged Digital to Address Persistent Water Leakage Problem, Improve Customer Engagement, and Reduce GHG Emissions⁵²

Context

In the mid-2010s, a major European city faced growing challenges in managing its expansive water distribution network, which stretches over 4000 kilometers, serving approximately 1.3 million residents across more than 50 municipalities. The network faced three critical challenges:

- **Water Losses:** The network experienced a high water loss rate⁵³ of 21%, exceeding the regulatory target of 15%.
- **Inefficient Customer Engagement:** Consumers lacked access to real-time water consumption data and did not receive proactive alerts for irregular usage. This limited their ability to manage consumption efficiently and make informed decisions about their water usage.
- **High GHG Emissions:** Excessive water losses and inefficient management led to unnecessary resource depletion, increased energy consumption, and higher carbon emissions associated with water treatment and distribution, undermining sustainability efforts. To be in line with the regulatory requirements, the utility needed to cut GHG emissions by 15%.

⁵²Source: BCG analysis, Expert interviews, Press releases

⁵³Water leakage rate refers to loss of potable water on a distribution network before water reaches the end user. Buried pipes, connections, and reservoirs can all be sources of leaks, leading to significant waste of water resources and incurring high production and treatment costs for utilities

Digital Transformation Journey and Interventions Taken

To address these challenges, the city engaged a major multinational water management company to drive an eight-year transformation which would enable it to reduce water losses, improve customer satisfaction, and help meet its emissions targets. The transformation strategy focused on the following key initiatives:

- **Advanced IT/OT Systems for Leak Detection:** The deployment of 5000+ fixed acoustic sensors and 500+ mobile sensors to allow for continuous surveillance of the most vulnerable sections of the network. These sensors were deployed to enable swift identification and repair of leaks, significantly reducing water loss.
- **Smart Metering Infrastructure:** The installation of 400,000 smart meters equipped with remote reading capabilities to provide customers with access to daily consumption data and alerts for abnormal usage. This initiative aimed to empower consumers to manage their water usage more effectively while facilitating accurate billing and early leak detection within customer premises.
- **Integrated Management Center:** The establishment of a centralized management center to enable comprehensive, real-time monitoring and control of the entire 4,000 km water network. This facility was designed to ensure full traceability of water quality, operational transparency, and proactive network management, facilitating instant decision-making and rapid response to issues. By continuously collecting and analyzing data across the network, it provided 24/7 surveillance, allowing for immediate emergency interventions, more efficient field force mobilization, and optimized water distribution, ultimately enhancing service reliability and efficiency.

Outcome

The digital transformation yielded substantial improvements in the city's water management:

- **Significant Reduction In Water Losses:** Within 3 years, the water losses reduced to 13%, enabling the network to meet the regulatory target. **The proactive leak detection system was instrumental in identifying and repairing over 1,000 leaks within three years, resulting in daily savings of 33,000 cubic meters of water.**
- **Improved Customer Engagement:** The smart metering system enabled customers to monitor their water usage in real-time, leading to more informed consumption habits and prompt identification of leaks on their properties. This transparency fostered greater trust and satisfaction among consumers.
- **Environmental Benefits:** The concerted efforts in leak reduction and operational optimization contributed to significant water conservation, aligning with the city's sustainability objectives and reducing the environmental footprint of water services. By enabling early leak detection and promoting more efficient water use, these initiatives helped reduce overall demand, minimizing unnecessary water extraction and treatment. This, in turn, **led to lower energy consumption for pumping and distribution**, as well as a significant reduction in the use of chemical additives for water treatment, contributing to both cost savings and environmental sustainability.

Encouraged by the success of the initial eight-year engagement, the **local government authority extended its partnership with the multinational water management company for another long-term project**. This initiative, which is currently ongoing, aims to enhance the efficiency of the city’s wastewater treatment system while achieving significant resource savings, including a 15% reduction in electricity consumption, a 72% decrease in gas usage, a 10% cut in water consumption, and a 50% reduction in the need for chemical additives through optimized plant management.

As we delve into the operationalization steps and Key Success Factors (KSFs) for digital transformation later in this chapter, we will elaborate on Case Study 4A to illustrate these in practice. As this case focuses on an emerging nation utility in the early stages of digital maturity, it offers practical insights and relatable lessons for many utilities globally navigating their own transformation journeys.

4.1 Steps in Operationalizing Digital Transformation for Water Utilities

Executing a successful digital transformation program requires a structured and strategic approach. In this section, we will outline a five-step process for the operationalization of digitalization, ensuring that water utilities can systematically assess their digital maturity, prioritize issues, identify innovative solutions, and effectively implement and evaluate digital initiatives.

Steps to Operationalizing Digital Transformation of Water Utilities

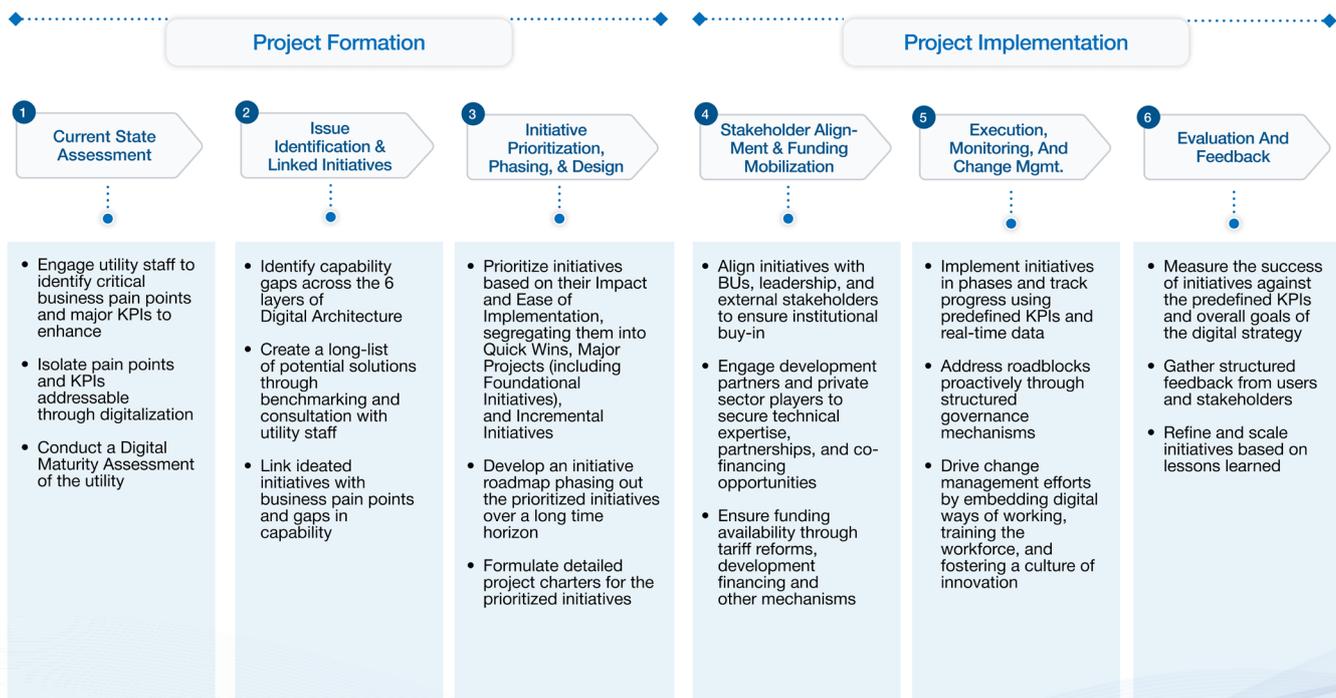


Figure 24: Steps to operationalizing Digital Transformation of Water Utilities

• Step 1: Current State Assessment

- Assess the current state of the utility by directly engaging the staff across various organizational levels, gathering insights into business pain points and major KPIs that need to be enhanced.
- Isolate the business pain points and KPIs that are addressable by digital technologies. **Refer to section 2.1 of this report where an illustration of major pain points and KPIs for water utilities has been provided**, highlighting those that can be potentially addressed by digital.
- Conduct a thorough Digital Maturity Assessment across six parameters (Digital Strategy, Digital Engagement, Digital Business Processes, Data Analytics and AI, Digital Infrastructure and Security, and Digital Organization, Talent, Ways of Working) **leveraging the Digital Maturity Assessment Framework provided in section 2.4**. This step may require utilities to engage external experts to ensure the assessment is aligned with global benchmarks, industry best practices, and emerging digital trends.

• Step 2: Issue Identification and Linked Initiatives

- Identify the current gaps in capabilities across the 6 layers (Engagement Channels, Data and Analytics, Integration and Data Exchange, Core Business Capabilities, Infrastructure, and Security and Identity Mgmt.) by referring to the **Ideal End State Digital Architecture for Water Utilities, provided in chapter 2.3**.
- After identification of gaps in capabilities, brainstorm a long list of potential initiatives that could be implemented to advance the digital vision of the utility. **Refer to chapter 2.5 for a reference set of initiatives that can be considered by utilities based on their current level of digital maturity**.
- Link the ideated initiatives with the identified capability gaps and business pain points of the utility.

• Step 3: Initiative Prioritization, Phasing, and Design

- Analyze the Impact (Degree of effect on KPIs and overall digitalization enablement, Operational Fitment, Effect on Profitability) and Ease of Implementation (Data Pre-requisites, Dependencies, and Resource/ Budget availability) to create a priority list of initiatives. This will help identify Quick Wins, Major Projects (Foundational and Other Critical initiatives), and Incremental Initiatives. **Refer to section 4.3, where we have provided a detailed framework for Digital Initiative Prioritization and Phasing**.
- Develop a long-term initiative roadmap with the prioritized initiatives.
- Formulate detailed project charters laying out objective/scope of project, key phases and activities, benefits/ impacts anticipated, major deliverables, team, risks and dependencies, prerequisites, and durations. **We have provided a sample project charter in Appendix B**.

- **Step 4: Stakeholder Alignment and Funding Mobilization**

- Align digital initiatives with internal business units, leadership, and external stakeholders (e.g., governments, regulators, and policymakers) to ensure institutional buy-in.
- Engage development partners and private sector players to secure technical expertise, partnerships, and co-financing opportunities.
- Ensure funding availability through a mix of tariff reforms, public and private sector investment, development financing, and blended finance mechanisms. **Refer to section 4.4 to check an estimation of costing for digitalization initiatives.**

- **Step 5: Execution, Monitoring, and Change Management**

- Implement initiatives in phases, starting with Quick Wins and Foundational Initiatives, while tracking progress using predefined KPIs and real-time data.
- Address roadblocks proactively through structured governance mechanisms, agile decision-making, and cross-functional coordination.
- Drive change management efforts by embedding digital ways of working, training the workforce, and fostering a culture of innovation and adaptability. **In section 4.2, we have further explained change management and agile governance** in the Key Success Factors as well as the deep-dive on Case Study 1.

- **Step 6: Evaluation and Feedback**

- Assess the impact of digital initiatives by comparing results against predefined KPIs, operational goals, and overall digital strategy benchmarks to measure effectiveness.
- Collect structured feedback from users and stakeholders through surveys, performance reviews, and workshops, ensuring insights are gathered from all levels of the organization.
- Refine and scale successful initiatives by incorporating lessons learnt, optimizing processes, and expanding high-impact solutions across the utility for sustained digital transformation. **Refer to section 4.2, where we provide further details on how utilities can evaluate the initiatives post-execution and adjust based on feedback.**

The case study below showcases how a South Asian utility initiated its digital transformation journey following the steps described above. We will continue to refer to this case study throughout this chapter as we look at the Key Success Factors (KSF) for successful digital transformation and strategies to mitigate common pitfalls.

4.2 Key Success Factors for Digital Transformation

In Chapter 3, we explored the transformative potential of digitalization for water utilities and how it can enhance performance across the entire value chain. **While digital transformation offers significant benefits, its success rate remains low – only 30% of transformations fully succeed, while the majority fall short of their ambitious objectives, only resulting in only marginal changes³⁷.** Failed transformations – which may be due to unclear strategy, leadership misalignment, cultural resistance, inadequate change management, technological limitations, talent shortages, or poor execution – can result in wasted investments, lost productivity, and missed opportunities.

While the overall success remains relatively rare for digital transformation projects overall, the success rate among organizations that get 6 Key Success Factors right is 80%. These factors have consistently driven successful transformations across industries, geographies, and varying scopes of digital initiatives. In this section, we will first explore these six critical factors and then dive deeper into how water utilities can leverage them to improve their chances of success in their digital transformation journey. The 6 key factors are:

1. An Integrated Digital Strategy with Clear Transformation Goals

A well-defined digital strategy is the foundation for a successful transformation. Water utilities must establish **clear objectives by articulating the why, what, and how of digitalization, all tied to tangible business outcomes.** A strong strategy should align digital initiatives with broader organizational goals, including but not limited to improving water quality, reducing leaks, enhancing customer service, and optimizing asset management. Additionally, utilities should prioritize high impact use cases, develop a phased roadmap, and ensure resource availability to drive execution.

2. Leadership Commitment from Executives Through Operational Teams

Successful digital transformation requires sustained commitment from senior executives, board members, ministry/government representatives down to operational teams. Utility leaders must champion digital initiatives, allocate resources strategically, and foster a culture of adaptability and innovation. Middle management plays a crucial role in execution and must be empowered with the right tools, training, and accountability measures to integrate digital practices into daily operations. Given that many water utilities operate within governance frameworks shaped by public bodies and regulators, it is even more critical for leadership to align digital strategies with policy objectives, regulatory mandates, and stakeholder expectations to drive long-term success.

³⁴BCG Analysis: Based on a study of 895 organizations, 18% of which were state owned enterprises, across Asia Pacific, Europe, South America, and North America; 35+ factors were considered in the study and 6 factors emerged as most important to driving the success (assessed on the % of targets and value met) of digital transformation

3. Deploying High-Caliber Talent

Water utilities often face workforce challenges, including skills gaps and resistance to adopting new technologies. A successful transformation requires investment in **digital upskilling** for employees, enabling them to operate and maintain new digital systems effectively. This includes providing hands-on training, knowledge transfer from digital partners, fostering a culture of innovation, and ensuring that digital teams are equipped with the necessary expertise.

4. An Agile Governance Mindset that Drives Broader Adoption

Water utilities often operate in complex environments with multiple stakeholders, regulatory constraints, and long-term infrastructure planning cycles. To successfully implement digital transformation, governance must be **flexible, transparent, and action oriented**. Instead of rigid, top-down decision-making, utilities should establish **cross-functional teams** that bring together IT, operations, customer service, and regulatory experts to ensure digital initiatives are aligned with both short-term operational needs and long-term strategic goals. Effective governance also means **removing bureaucratic bottlenecks** that slow down technology adoption. Utilities should streamline approval processes, establish clear decision-making structures, and ensure that digital transformation efforts remain a priority amid competing operational demands. By adopting **agile governance**, water utilities can accelerate digital adoption, drive cross-functional collaboration, and ensure that transformation efforts lead to lasting, system-wide improvements.

5. Effective Monitoring of Progress Towards Defined Outcomes

To ensure digital transformation delivers real benefits, water utilities must **establish clear performance metrics** that measure both operational and service outcomes. This includes tracking key indicators such as leak detection rates, energy efficiency improvements, customer response times, and asset health. A dedicated **Transformation Management Office (TMO)** can oversee progress, ensure accountability, and help address implementation challenges. Additionally, water utilities must improve data collection and integration, creating a **single source of truth** for operational and financial performance. Reliable, high-quality data is essential for informed decision-making and proactive problem-solving.

6. Building on a Scalable and Modular Digital Architecture

A modern, fit-for-purpose digital architecture is essential for secure, scalable performance, rapid deployment of changes, and seamless system integration. The architecture should be flexible and modular, enabling continuous upgrades without disrupting existing operations. A phased modernization approach is crucial to integrating legacy systems with new technologies, ensuring alignment with the overall digital strategy. Furthermore, it is essential to **identify and address key prerequisites** before initiating the implementation of digital initiatives to **prevent delays and ensure seamless execution.**

Revisiting Case Study 4A: Operationalization and Key Success Factors of Digital Transformation in Practice

When the South Asian utility embarked on its digital transformation journey, it partnered with a major development organization, which brought in a team of consultants to **develop a comprehensive Digital Strategy** aligned with global best practices and the utility's operational needs while also facilitating its initial implementation and execution. This collaborative effort followed a structured approach, incorporating the **six-step operationalization framework** outlined in **section 4.1**, while also leveraging the six **Key Success Factors (KSFs)** discussed in **section 4.2** to address challenges and drive sustainable impact.

The utility's transformation journey began with a detailed **assessment of its current state**, where the consultants helped evaluate the utility's existing digital maturity, operational inefficiencies, and key capability gaps across the utility's overall digital architecture. This was followed by **Issue Identification and linking initiatives**, where specific capability gaps were linked to potential digital initiatives through stakeholder consultations and benchmarking. Next, a **detailed prioritization and phasing exercise was conducted** through which a total of **27 digitalization initiatives** were identified and prioritized. These initiatives were then **aligned with the Steering Committee**, comprising leadership of both the utility and the development partner to ensure stakeholder alignment and funding availability. Following this, **three out of the 27 initiatives were implemented** as quick wins to demonstrate impact and build momentum. Following this, to build momentum for the digital transformation and deliver immediate impact, **three quick-win initiatives** were selected from the 26 proposed initiatives. **To facilitate execution effectively**, a local vendor was engaged to support both the technical development and change management efforts. Finally, the utility leveraged real-time insights from dashboards and institutionalized a structured governance framework to track implementation progress. **Monthly senior leadership meetings** were established to review key performance indicators (KPIs), address challenges, and ensure accountability. For instance, the utility set a target of generating 70,000+ bills per month following the full rollout of the Meter Reading App (MRA) and aimed to achieve 100% accuracy in meter reading data through operator verification. Additionally, an **iterative feedback loop was introduced**, allowing business units to provide input during the testing phase. This enabled continuous feature enhancements and refinements based on user needs. As a result, over 20 new data visualizations and analytics tools were added to the Management Dashboard, improving usability and decision-making capabilities.

As of this writing, these quick-win initiatives have been operational for three months, and the utility incurred a total cost of ~USD 300,000 in capital expenditure as well as operating expenditure till date, significantly below the originally estimated USD 400,000 – 500,000 range, showing that efficient resource utilization and execution can minimize costs.

While the **utility had developed an integrated digital strategy with clear transformation goals** and **adopted effective monitoring practices**, there were **4 critical challenges** in the implementation of the quick-win initiatives:

1. Resistance to Change

When the Meter Reading App (MRA) was introduced, Meter Inspectors (MIs) initially resisted the transition, preferring legacy processes and lacking strong incentives to change. To encourage adoption, the utility is considering the implementation of a Rewards and Recognition (R&R) program, which will establish rewards for high performers who consistently used the app. **This highlights why it is critical to drive commitment from the top-level through operational teams to ensure success.**

2. Limited Talent Availability and Readiness

During the implementation of the quick-win initiatives, **the need for digital upskilling became evident.** MIs struggled with the Meter Reading App, facing difficulties with handheld devices, GPS tagging, and digital workflows. Similarly, utility officials found it challenging to transition from paper-based approvals and manual logs to automated tracking systems, affecting bill approvals and issue resolution. Revenue department officers also required time to adapt to the Management Dashboard, particularly in KPI tracking, trend analysis, and anomaly detection, as they were accustomed to working with manual data. **To address this challenge, customized training and hands-on demonstrations were organized for the MIs and utility officials.**

3. Policy Barriers Slowing Adoption

The utility's policy required customers to bear the full cost of meter replacements, causing delays in replacing faulty meters, which in turn impacted accurate billing through the MRA. Additionally, there was no clarity on policies related to lost electronic/mobile devices from the field force. This highlighted a critical misalignment between policy frameworks and digital transformation goals, reinforcing the need for leadership intervention to revise outdated policies and facilitate smoother transitions to digital workflows. **This underscores the importance of getting early buy-in from and alignment with all stakeholders.**

4. Integration of Technology and Infrastructural Readiness

During the implementation of quick-win initiatives, the South Asian utility faced challenges in integrating data from its Water Billing System, SCADA, and databases – each **built on different tech stacks with limited interoperability.** The disparate data sources and inconsistent formats created challenges in maintaining data quality. Furthermore, the utility had limited access to the vendor-controlled systems such as SCADA. This required custom ETL (Extract, Transform, Load) processes to synchronize data with the Operational Data Store (ODS), adding complexity and inefficiencies. **Additionally, integrating the Meter Reading App (MRA), Management Dashboard, and NRW Monitoring Tool with the Billing System demanded complex API development,** limiting real-time data synchronization to twice a day and restricting real-time decision-making. Moreover, the **existing IT infrastructure of the utility was inadequate,** as it lacked the electrical and cooling capacity needed for the additional servers. The under-configured servers also struggled to handle high transaction volumes during peak synchronization times. As such, the server room had to be expanded, and electrical capacity needed to be augmented to host the quick win solutions that were implemented. Beyond this, multiple data schedulers were implemented to stagger updates and optimize performance, balancing real-time data needs with limited server capacity. **This is why it is crucial to ensure scalability and modularity of the overall digital tech architecture.**

Looking forward, the utility plans to further enhance its efforts to **cultivate high-caliber talent** and **adopt an agile governance mindset** to drive the long-term success of its digital transformation. As part of its digital strategy, **the utility has adopted a structured, phased approach to expanding its digital talent pool**. Currently, a small core team of 3-4 digital specialists is engaged in the planning, design, and operations of quick-win initiatives, supported by external consultants, while the development of solutions is being done by a digital partner. As the transformation advances, the utility plans to progressively develop in-house expertise, enabling its team to work with digital partners directly in planning, design, build, and operations. In the final phase, the utility aims to establish a fully scaled digital team, sized according to the volume and complexity of digital initiatives, ensuring it has the necessary capabilities to drive and sustain long-term digital innovation.

To drive agility across the organization, the utility is considering to establish a Digital Center of Excellence (DCoE) as a potential long-term solution. The DCoE is currently envisioned to be a centralized unit with a core team of experts to drive synergy across functions, while execution remains embedded within each business unit. This model will help align the DCoE's priorities with representatives from different departments, ensuring digital initiatives are business-driven while maintaining centralized oversight of critical IT infrastructure. Additionally, this approach will require limited upfront investment, while helping the utility strike a balance between strategic governance and decentralized execution of digital initiatives.

4.3 Digital Initiative Prioritization and Phasing Framework

As discussed in the previous section, a key component of an integrated Digital Strategy is a well-defined initiative roadmap with prioritized initiatives for implementation to advance digital capabilities. In this section, we will provide a Digital Initiative Prioritization and Phasing Framework which will enable utilities to assess each initiative for its priority level, prerequisites, and contribution to the organization's transition across different levels of digital maturity.

Outlined below is the three-step process for the strategic implementation of digital initiatives:

- **Step 1: Develop a Long List of Initiatives**

Create a long list of potential initiatives through a comprehensive benchmarking exercise and consultation with utility leadership. This step ensures that all possible major initiatives are considered before narrowing down the list.

- **Step 2: Prioritize Initiatives**

In this step, utilities should assess the ideated initiatives based on Impact and Ease of Implementation. This assessment includes consideration of several factors:

- **Impact Factors**

- Effect on Key Performance Indicators (KPIs) and overall digitalization enablement
- Operational Fitment within existing processes
- Potential financial impact on Profit and Loss (P&L)

- **Ease Of Implementation (Eol) Factors:**

- Data prerequisites
- Dependencies
- Resource and budget availability

Under of Eol, resource and budget availability are critical consideration for many utilities in emerging markets. When utilities have funds earmarked for specific initiatives from the government or development partners, it significantly bolsters the ease of implementation.

Digital Initiative Prioritizations and Phasing Framework

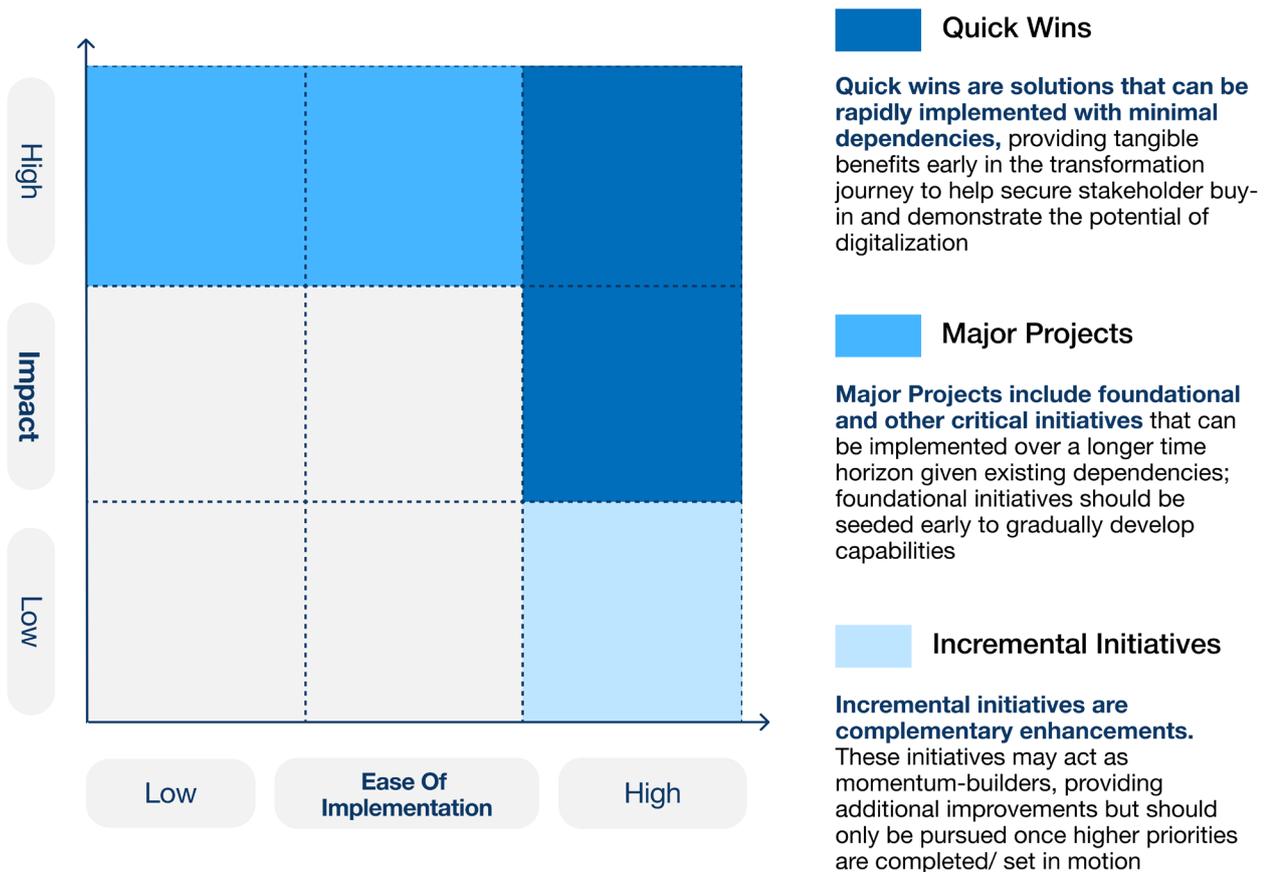


Figure 25: Digital Initiative Phasing and Prioritization Framework

- **Step 3: Phasing of Initiatives**

The final step involves phasing of initiatives after the prioritization exercise. Once the prioritization is complete, a utility will have 3 archetypes of initiatives for consideration:

- **Quick Wins:** To be implemented at the onset of the digital transformation journey. Quick Wins help demonstrate early success, build confidence among stakeholders, and create momentum for larger-scale initiatives. These initiatives typically involve minimal dependencies and can be rapidly executed to generate tangible benefits.

For a utility in an early stage of maturity, a Meter Reading App (MRA) to automate meter readings and improve collection efficiency may be a quick win.

- **Major Projects:**

- **Foundational Initiatives:** These initiatives have an overarching impact across the digital architecture and will serve as the backbone for future digitalization projects. Foundational initiatives should be initiated early in the transformation process so that they can support the future integration and scalability for more advanced technological solutions. Unlike quick wins, these initiatives will not deliver immediate impact, but they need to be initiated early as they will significantly enhance the ease of implementation of other critical initiatives. For instance, Data Platform and Security & ID management may be considered foundational initiatives for a utility at an early level of digitalization as they form the core of Data and Analytics and Identity & Security layers of the digital technology architecture.
 - **Other Critical Initiatives:** Essential projects that drive transformative change but require phased implementation due to resource constraints, dependencies, or regulatory considerations. These initiatives should be rolled out in sequential waves over the transformation timeline as the necessary prerequisites are gradually met, ensuring that each phase builds upon the previous one.
- **Incremental Initiatives:** These are easy to implement and “nice-to-have” improvements that can optimize efficiency or enhance specific workflows but do not significantly alter the utility’s operational landscape. They should only be pursued if resources are available and if higher-priority initiatives are already in motion or completed.

Initiatives that are lower on both impact and EoI may be deprioritized in the near term to focus resources on more strategic, high-value initiatives. However, these initiatives can be reassessed over time as the utility’s digital maturity increases, technologies evolve, or resource availability improves, which may lead to these initiatives being more impactful and easier to implement.

4.4 Costing Estimation for Potential Priority Initiatives

So far in this chapter, we have discussed the steps in operationalizing digital transformation, Key Success Factors (KSF) to derive the most value out of transformation, and prioritization and phasing of initiatives. Now we will examine the potential investment requirement for digital transformation.

This section provides a reference cost estimation for select digital initiatives that may be implemented by utilities. Refer to Section 2.5 for more descriptive definition of each of the initiatives covered in this section. The estimation begins with an outline of certain characteristics that have been assumed for undertaking this costing estimation. The final cost estimate for a utility may vary depending on how these parameters differ basis their individual context. The following exhibit highlights the characteristics assumed in the estimation:

Characteristics of Water Utilities for Cost Estimation

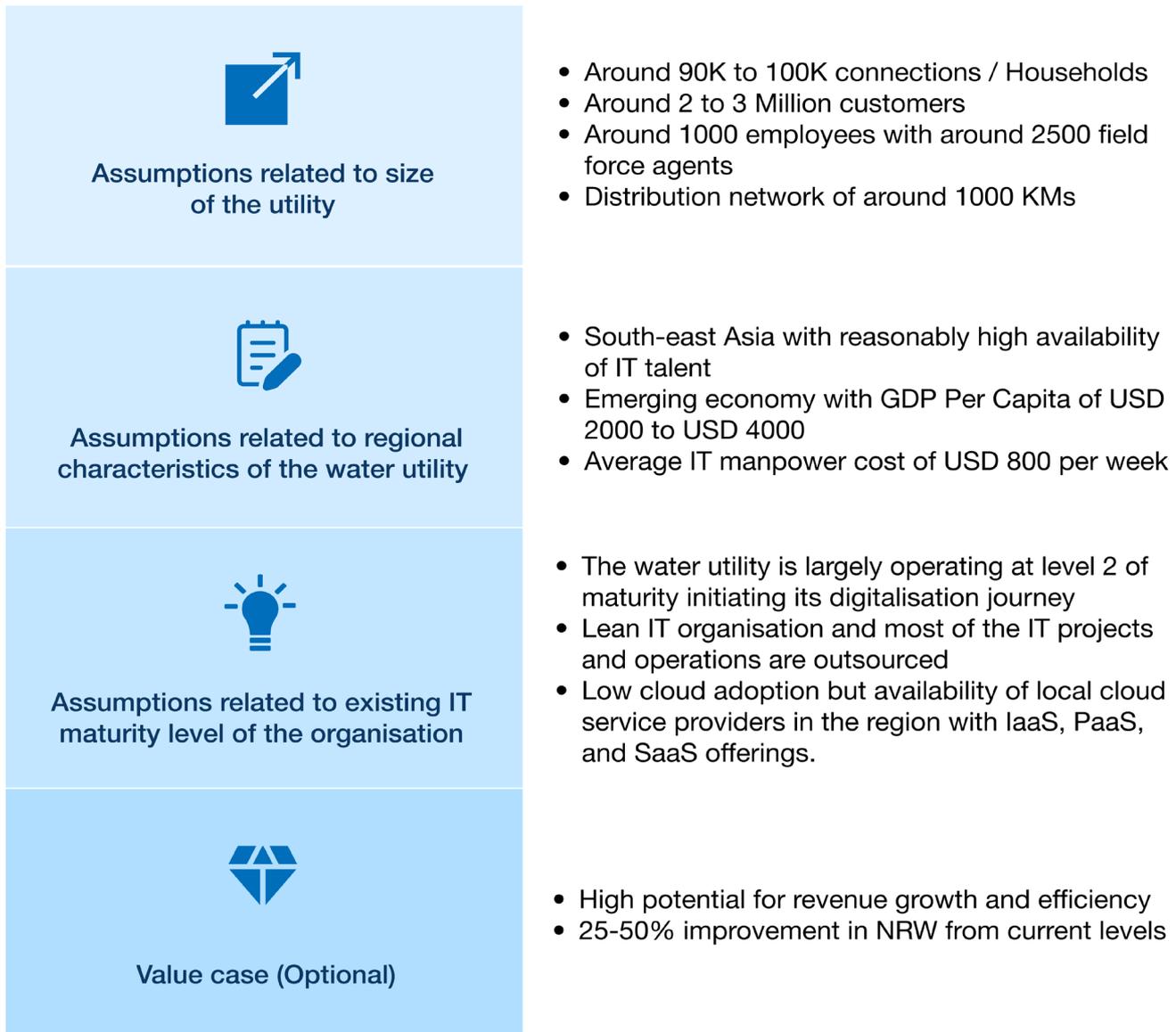


Figure 26: Assumed characteristics of Water Utility for Cost Estimation

The below tables describe the estimated cost investment⁵⁵ (CAPEX and OPEX) required for a utility at each level of digital maturity to progress to the next level, in line with the initiatives for progression outlined in Section 2.5. As mentioned previously, these should not be considered an exhaustive set of initiatives. The CAPEX includes implementation resource cost, off-the-shelf software cost, and hardware costs. The OPEX includes ongoing software enhancements/ fixes (AMS), hardware maintenance (ATS), software maintenance (AMC), IT support costs, and cloud subscription costs. The OPEX figures provided in the tables on pages 77-81 are for 1 year only. The calculations do not include other cost heads such as consulting/ advisory fees or regulatory and legal costs that may be involved in overall project formation and execution.

⁵⁵Source: JICA and BCG case experience and analysis, Expert interviews, Original Equipment Manufacturer (OEM) consultations

Initiatives implemented by water utilities at **similar maturity levels and high interdependence are typically implemented together**. For planning purposes, these interconnected initiatives have been **grouped together while representing the estimated costs**. For instance, management dashboard and NRW monitoring dashboard will have a **similar technical implementation approach**; hence, these are clubbed together while discussing their cost estimates.

Note that the descriptions provided here are illustrative and non-exhaustive. **The costing of initiatives for a given utility could fall outside the ranges provided below if a utility’s context significantly varies from the assumed characteristics shared above**. Furthermore, note that the tools/ solutions mentioned in the description column of the table below are examples for purposes of illustration and should not be considered as recommendations.

Level 1 to Level 2

Initiative	Description	CAPEX In Mn USD	OPEX In Mn USD
Customer Relationship Service	Basic inquiries, complaints and request mgmt. (E.G. Zoho call center solution, Cloudtalk etc.)	0.2-0.3	0.05-0.1
Digitize Water Infrastructure	Sensors, IOT gateway, network and communication infra	3-3.5	0.5-0.7
Grand Total		3.2-3.8	0.6-0.8

Level 2 to Level 3

Initiative	Description	CAPEX In Mn USD	OPEX In Mn USD
Mobile Apps for Customer Servicing and Meter Reading	Customer facing mobile app for bill payments, services. Mobile app for field agents for meter reading & billing.	0.7-1	0.2-0.3
Data Platform (Ingestion, Storage and BI)	Cloud based Data Platform; ETL/ ELT, CDC, ODS, BI tool (Opensource stack including Apache NiFi, Airflow, Hive, Hadoop, Griffin, MDM etc. or Cloud data stack from CSPs like GCP, AWS) BI tools such as Qlik, Sisense etc.)	1-1.5	0.6-0.8
Management Reporting and NRW Monitoring	MIS dashboards for insights and decision-making including dashboard for tracking and reporting non-revenue water.	0.3-0.5	0.1-0.2
Infrastructure and Security Modernization	Hybrid cloud adoption, network and connectivity, centralized identity and access management. Single-sign-on, Multi-factor authentication tools (e.g. Keycloak etc.)	1-1.2	0.2-0.3
SCADA System	Automated data acquisition from sensors, flow meters, centralized data analysis (e.g. Siemens SIMATIC, GE Predix etc.)	2.5-3	0.7-0.9
Grand Total		5.5-7	2-2.5

Level 3 to Level 4

Initiative	Description	CAPEX In Mn USD	OPEX In Mn USD
Field force management app and field-force CRM with modern integration management and device management	Cloud based CRM tool (e.g. Zoho CRM etc.) for field force management. Field force mobile app for beat planning / scheduling, dispatching, tracking (e.g. MapBox, Zoho). Device mgmt. system (e.g. intune, Airflow etc.) will securely manage field force devices (around 250 approx.) Integration platform for API-based integrations (e.g. Istio, Kong etc.)	1-1.5	0.3-0.5
Master Data Management and Analytics Platform	Master Data and Reference data hub (e.g. Apache MDM, GCP cloud data catalog etc.) Data science workbench tool for performing analytics across value chain (e.g. Apache Spark, Zeppelin, Jupyter Notebook etc.)	1-1.5	0.3-0.4
GIS based Infrastructure Planning Tool	Design, development, and integration of GIS based infra planning tool (e.g. ArcGIS etc.)	2.5-3	0.7-0.8
Enterprise Resource Planning (ERP) and Operational Gain System	ERP tool with financial management., asset management., HR, supply chain, inventory management. etc. (e.g. Upande ERP, Odoo ERP etc.) Operational gain system for energy and chemical dosage optimization etc.	3.5-4	0.8-1.0
Grand Total		8-10	2-3

Level 4 to Level 5

Initiative	Description	CAPEX In Mn USD	OPEX In Mn USD
Customer Relationship Modernization and Supplier / Partner Relationship Management (CRM and SRM)	Annual subscription for an affordable fit-for-purpose on-cloud CRM with customer onboarding, servicing, relationship management. (e.g. Zoho CRM, Zendesk etc.) Annual subscription of cloud-based supplier relationship mgmt. system (e.g. Zoho SRM, Zendesk SRM etc.)	0.5-1	0.4-0.5
AI/ML initiatives including Forecasting & Planning Tools	Development of AI/ML models for select use cases as shown in Figure 20 in section 2.6 and integration with forecasting and planning tools such as Hydraulic modeling, demand forecasting etc. Opex includes annual cost of continuously training and updating the models ⁵⁶ by a team of data scientists.	1-1.5	0.5-1
Smart Metering Infra	AMR and AMI based smart meters – approx. 90K devices & installation (e.g. Sensus, L&T SmartWorld etc.)	11-14	0.5-1
Grand Total		13-17	1.5-2.5

⁵⁶AI models for 4 select use cases as listed in figure 15 in section 2.6. The Opex can vary depending on factors such as quality of underlying data, preparation of data, volume of data, training time etc.

Level 5+

Initiative	Description	CAPEX In Mn USD	OPEX In Mn USD
Municipal Level Control Centre for Operations and an integrated Disaster & Emergency Response Platform	Licenses, implementation and operationalization cost for centralized control center (e.g. BEL, GESAB etc.) Design, development, integration of disaster and emergency response platform.	4.5-5.5	1-2
Grand Total		4.5-5.5	1-2

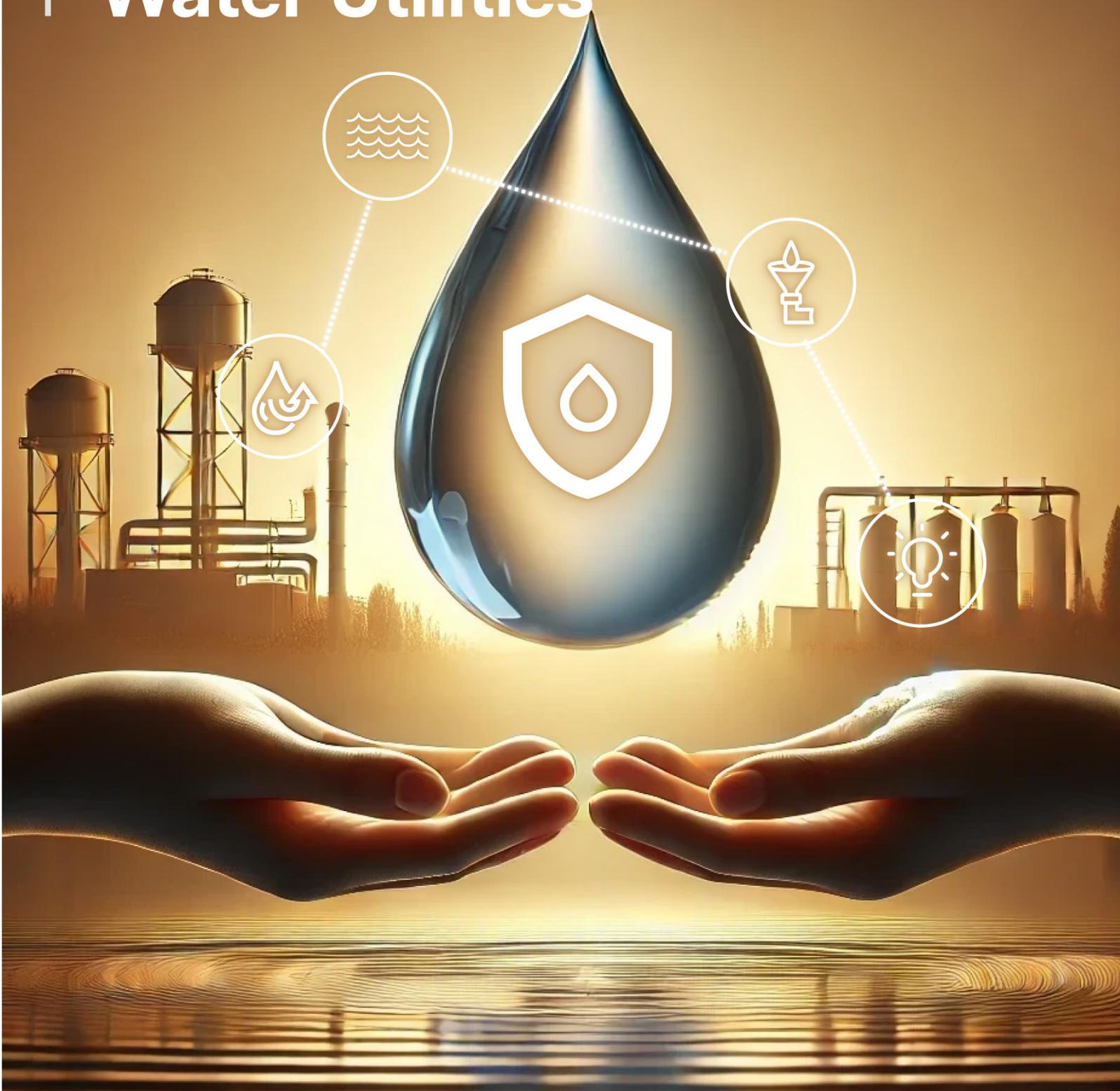
As evident from this section, the overall cost of digital transformation for a utility will be in several millions of dollars, depending on the overall context and starting point of digital maturity.

To manage the investment required for digital transformation, utilities often collaborate with development partners who provide financial support, technical expertise, and strategic guidance.

Development partners help offset capital and operational expenditures through grants and concessional financing. By leveraging these partnerships, utilities can reduce immediate financial strain, enhance affordability, and ensure the long-term sustainability of their digital initiatives.

Chapter 05

Looking Ahead—A Future with Digitally Empowered Water Utilities



The global water crisis is escalating, with demand expected to exceed supply by 40% within the next five years.⁵⁷ Water utilities must play a pivotal role in ensuring water security for all, and to do so, they must fundamentally transform how they operate.

Chapter 1 introduced the pressing need for digitalization, highlighting the challenges that keep many utilities trapped in a **vicious cycle**. **Chapter 2** then examined the pain points and KPIs of utilities in detail, demonstrating how digital technologies can be leveraged to drive meaningful change. It also provided a structured framework for assessing digital maturity and outlined the journey from traditional, paper-based operations to advanced, digitally empowered utilities.

Chapter 3 built the case for digital transformation by illustrating its far-reaching benefits – not only for utilities but also for society, the economy, and environmental sustainability. **Chapter 4** then presented a step-by-step guide for utilities to embark on and scale their digital transformation, emphasizing key success factors to ensure lasting impact. Through real-world case studies, we explored both the tangible gains and potential pitfalls of digitalization, and we provided cost estimates to support strategic investment planning.

Now, in this final chapter, we shift our focus to the **path forward** – emphasizing the critical role of collaboration in accelerating digital adoption. A sustainable, digitally driven water sector can be best achieved through **collaboration** among **utilities**, **governments**, and **development partners**. This chapter explores why multi-stakeholder engagement is essential and defines the roles each must play in driving this transformation to secure a more resilient and efficient water future.

5.1 Need for Collaboration

Digital transformation presents a significant opportunity to drive the growth of water utilities, enhance efficiency, and ensure financial sustainability. However, several **key challenges** must be addressed to realize its full potential:

Limited Ability of Utilities to Attract Investment

Water utilities, especially in emerging nations, often face widespread financial instability of water utilities, which limits their ability to generate earnings for reinvestment and undermines their creditworthiness, restricting access to external financing. Many utilities remain dependent on scarce government and concessional funding to sustain and expand their services. In emerging nations, **only 9% of funding in the water sector comes from private sources**, compared to 87% and 45% in telecommunications and power sector respectively⁵⁸.

⁵⁷United Nations, Retrieved from: [Half the World to Face Severe Water Stress by 2030 unless Water Use is "Decoupled" from Economic Growth, Says International Resource Panel](#). ⁵⁸Source: Water Aid. Retrieved from: [Mobilising capital for water: blended finance solutions to scale investment in emerging markets | WASH Matters](#)

Inefficient Planning and Fund Mobilization

Investment in digital infrastructure alone is not enough. To maximize impact, utilities must **develop a well-informed digital strategy** that aligns with sectoral priorities and ensures that technology investments are effectively leveraged. **Despite the funding shortfall, only 72% of the budgeted funds in the water sector are used**, compared to 89% in agriculture and 99% in human development sector respectively⁵⁹. This underutilization underscores the urgent need for a strategic approach that ensures available funds are effectively allocated, optimized, and translated into impactful initiatives.

Need for Enabling Conditions

Effective policies, cost-reflective tariffs, and improved governance structures will be essential to accelerating digital transformation. Governments and regulators **can play a key role** in removing barriers **to investment, streamlining regulations, and creating an environment that enables utilities** to operate in a financially viable and efficient manner.

Digital Skills Gap

Having the right technology alone is not enough – the success of digital transformation depends heavily on the capacity of utility staff to utilize these technologies effectively. Many utilities lack the technical expertise in their workforce that is required for digital adoption, making **upskilling programs, technical training, and digital literacy initiatives** essential.

To overcome these barriers, **utilities, governments, and development partners can work together** to create an ecosystem that supports digital transformation. A coordinated approach is needed to mobilize funding, develop enabling regulatory frameworks, build institutional capacity, and ensure utilities can implement and sustain digital solutions effectively. Achieving **financially sustainable and efficient water utilities** requires more than just recognizing the need for change – it requires **deliberate action**.

5.2 Call to Action

Ensuring sustainable, resilient, and financially viable water utilities requires a shared commitment from utilities, governments, and development partners. Digital transformation offers a powerful opportunity to modernize water management, enhance efficiency, and expand access. By aligning efforts, mobilizing resources, and fostering innovation, stakeholders can drive lasting progress, ensuring a water-secure future for generations to come.

⁵⁹Source: World Bank and World Economic Forum. Retrieved from: [Why investment in water is crucial to tackling the climate crisis | World Economic Forum](#)

- **Utilities** can

- **Develop a comprehensive digital strategy** by working closely with industry experts and development partners to align digital transformation initiatives with organizational priorities and national-level policies and targets.
- **Collaborate with governments** to formulate enabling policies and advocate for tariff reforms that support financial sustainability and encourage investment in digital infrastructure.
- **Strengthen workforce capacity** by hiring specialized talent and collaborating with development partners and private sector players to implement upskilling programs, ensuring employees can effectively operate and sustain digital systems for long-term success.

- **Governments** can

- **Create an enabling environment** by implementing supportive policies, regulatory frameworks, and sector reforms to enhance financial viability and attract investment. This includes but is not limited to enforcing cost-reflective tariffs that promote financial viability of utilities.
- **Facilitate private sector participation** through Public-Private Partnerships (PPPs), performance-based contracts, and incentive mechanisms to improve service delivery and operational efficiency.
- **Promote digital adoption** by integrating smart water management technologies into national water strategies and supporting pilot projects for innovation.

- **Development Partners** can

- **Provide investment and co-investment opportunities** by offering blended finance solutions, grants, and concessional loans to de-risk private sector participation and support the scaling of digital infrastructure in water utilities.
- **Support utilities in developing and implementing digital strategies** by providing technical assistance, knowledge-sharing platforms, and capacity-building programs to ensure effective adoption and integration of digital solutions.
- **Help create an enabling environment** by working closely with governments to facilitate informed policy and regulatory reforms, economic incentives, and governance improvements that facilitate digital transformation and attract sustainable investments in the water sector.

Appendix A: Detailed Breakdown of Ideal Technology Architecture for a Utility

1. Engagement Channels



Figure 27: Engagement Channels

Engagement Channels help utilities **connect efficiently with customers, employees, and external partners** like government and weather agencies. These channels include apps, emails, call centers, chatbots, and online portals, making communication and services more accessible and seamless.

- **Customer touchpoints** include the following:

- **Customer Servicing Portal:** A self-service web portal where customers can check their billing, payments, water usage, and request services.
- **Physical Mail:** Mail room management for tracking and organizing physical mails
- **Call Center and IVR:** Customer support system with Interactive Voice Response (IVR).
- **Customer Mobile App:** App to enable customers to manage bills, complaints etc.
- **Messaging Services (WhatsApp):** Send notifications like reminder, updates etc.
- **SMS:** Send notifications and alerts on SMS by integrating with an SMS gateway.
- **Email:** Send email notifications, receive requests on / from registered email IDs.
- **Kiosks:** Self-service payment stations available at utility offices or public locations.
- **AI-Enabled Chatbot:** AI enabled responses for customer queries and requests.

- **Workforce touchpoints** include the following:

- **Workforce Portal:** A portal for field force to interact with the water utility.
- **Mobile Device Management:** Securely manage workforce devices.
- **Meter Reading App:** Field force to log water meter readings, generate bills etc.
- **Employee Mobile App:** Field force track assigned tasks and reports on work orders.
- **Management Dashboards:** Internal reporting platforms for insights and decisioning.
- **Intranet:** Portal for staff members to avail HR, Payroll, admin, IT related services etc.
- **Early Warning Systems:** Centralized alert and predictive notification management systems for centralized monitoring of key KPIs and raise alerts to trigger remediation actions.
- **PoS Devices:** Devices to collect customer bill payments and generate receipts.

- **External/Third-Party integrations** include the following:

- **Social Media:** Social media listeners to monitor, analyze, and respond to public conversations on social media platforms like X , Facebook etc.
- **Weather Services:** Integration with weather services for gathering meteorological data for analysis and optimize water resources.
- **Space Agencies:** Integrating with space agencies for gathering satellite imagery for improving water management, detecting leaks etc.
- **Payment Gateway:** Enables seamless bill payments. In an ecosystem play, the water utility can expose APIs using which the payment aggregators can fetch the billing and invoice data and provide bill presentment and collection services.
- **Banking Services:** Water utilities integrate with banks and fintech institutions that provide services such as customer account management (virtual accounts) that enable billing and arrear management, security deposit, refunds and more.
- **Govt. Agencies:** Other govt. agencies including municipalities, other water utilities, urban / rural development and planning institutions integrate with water utilities for holistic planning and development.

2. Data and Analytics

The Data and Analytics layer **handles everything related to data** – collecting, storing, organizing, and analyzing it. It also includes AI tools to help make smarter decisions and improve services.

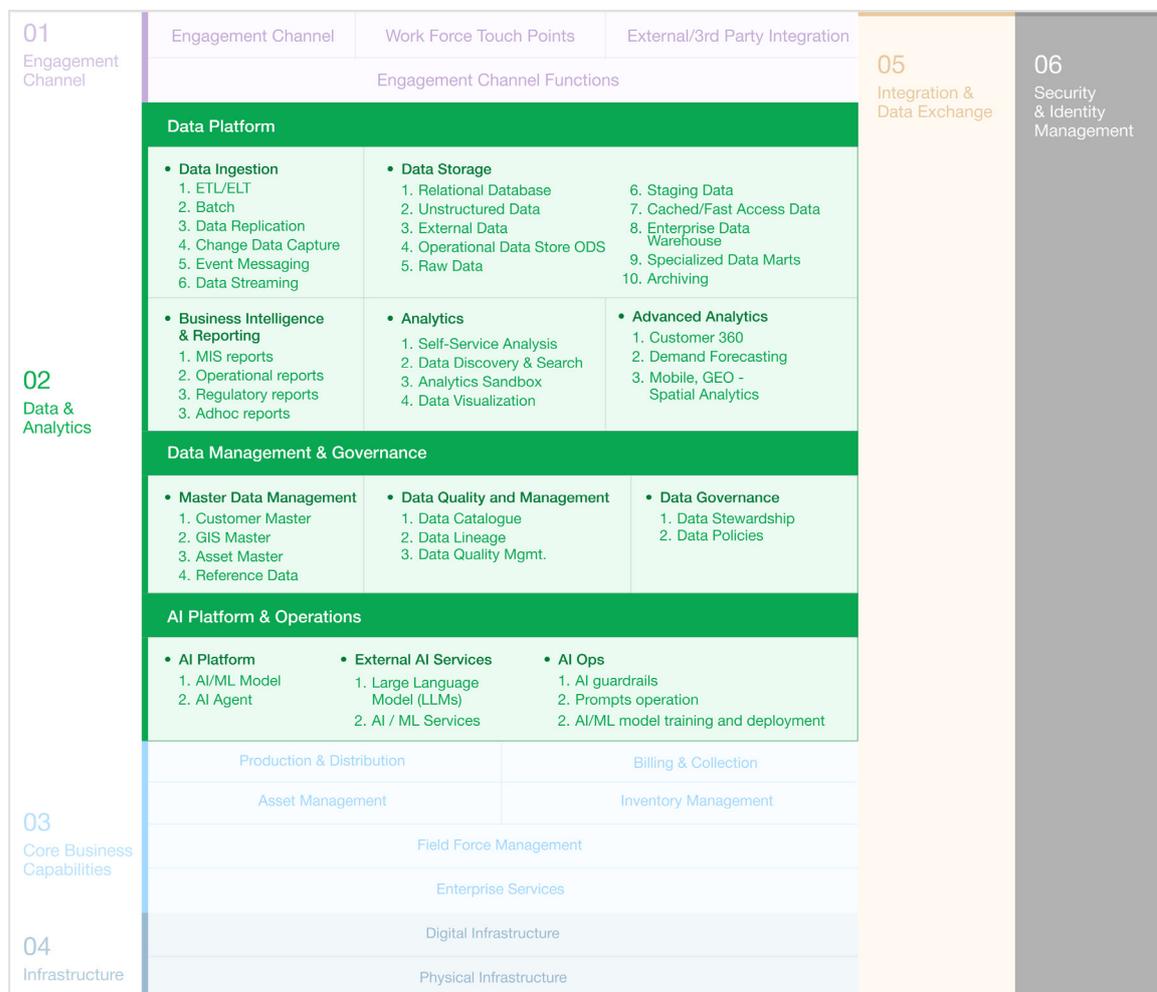


Figure 28: Data and Analytics

Data Platform

This component serves as the single source of truth for storing, managing, and accessing all water utility-related data. It integrates data from core business systems, IoT devices, SCADA systems, GIS, CRM, and financial systems into a unified ecosystem. The key components of Data Platform include:

- Data Ingestion:** ensures that data from smart meters, SCADA systems, IoT sensors, weather services, and customer platforms is accurately collected, cleaned, processed, and delivered to different applications. It includes the following capabilities:
 - ELT / ETL: ETL** (Extract-Transform-Load) / **ELT** (Extract-Load-Transform) tools enable ingestion of data covering capabilities such as cleansing, normalizing, and enrichment of data from source systems before storage.
 - Batch:** non-real time (periodic) ingestion of data from source systems into Data Platform leveraging ETL / ELT tools. This is carried out using batch scheduling systems that automatically run scheduled jobs at a set frequency.

- **Data Replication:** Replicates data from operational databases of source systems to the raw data storage layer in the Data Platform.
 - **Event Messaging:** Event driven architecture is enabled by technologies like Apache Kafka, RabbitMQ and MQTT for real time streaming in use cases where there is a need to notify relevant systems immediately when an event occurs (e.g., anomalies are detected).
 - **Change Data Capture:** Synchronizes changes between transactional databases and analytics platforms
 - **Data Streaming:** Water utilities need real-time data processing to react instantly to system changes and optimize performance. It uses technologies like Apache Kafka and Apache Flink for high-speed real time data streams, Spark streaming for processing large amount of sensor data.
- **Data Storage:** Water utilities manage large volumes of structured and unstructured data, requiring multiple storage solutions tailored to different operational needs, as listed below:
 - **Raw Data:** Data from source system gets replicated as-it-is in the raw data zone of the Data Platform for further cleaning, processing, and restructuring.
 - **Operational Data Stores:** Acts as an intermediate storage layer between operational systems (SCADA, billing, CRM) and the data warehouse, mainly to facilitate quick retrieval and near real-time reporting.
 - **Enterprise Data Warehouse:** Stores structured, historical data for reporting and analytics and serves as a single source of truth for enterprise decision-making.
 - **Cached / Fast Access Data:** Caching is a mechanism used to enable fast access of data for better performance of the system. Caching systems provide a high-performance data structure to enable quick search and read operations. Frequently accessed data is recommended to be cached to speed up performance and reduce load on the source system databases.
 - **Staging Data:** In a Data Platform, staging data is a temporary storage area where raw data is processed and transformed before being loaded into the final target system, such as a data warehouse, data mart, or data lake. This provides improved data quality and consistency needed for Analytics, AI/Models to work effectively.
 - **Relational Databases (RDBMS):** this is the most basic storage for any business application mainly to store structured data.
 - **Specialized Data Marts:** Data marts are subsets of the EDW optimized for specific business units e.g., an asset management data mart is created to specifically track pipeline maintenance, SCADA logs and GIS data, Revenue Data Mart is created to analyze unpaid bills and design better payment plans for customers.

- **Unstructured Data:** Data lakes store massive volumes of raw data that can be structured, unstructured or semi-structured to facilitate AI based decision making in real time. Unstructured is used in applications that handles non-tabular and large-scale unstructured / semi-structured data e.g., sensor data, images.
 - **External Data:** A water utility sources data from external agencies and other water utilities like satellite imagery, weather data and more. This data also gets ingested into the Data Platform for holistic analysis for decision making.
 - **Data Archives:** Provide cost effective yet efficient long-term storage of historical billing records, regulatory reports, GIS maps, and customer complaints and others. that may or may not be retrieved later as per industry regulations.
- **Business Intelligence and Reporting:** The BI and reporting capability in a water utility transforms raw data into insights that are easy to understand through dashboards, graphs, heatmaps, and reports. This layer is crucial for utility managers, engineers, field technicians, and customer service teams to monitor operations, identify trends, and make data-driven decisions in real-time. This will enable various types of use cases like:
 - **MIS Reports:** Provides live updates from SCADA, IoT, and smart meters. Also, dashboards for NRW monitoring.
 - **Adhoc Reports:** BI tools like tableau, powerBI enable users to slice and dice the data by adopting self-service reporting via role-based access control mechanisms.
 - Regulatory reports as required to be shared with various regulators such as public utility boards established by various governing bodies as per the laws of the land.
 - Regulatory reports as required to be shared with various regulators such as public utility boards established by various governing bodies as per the laws of the land.
 - Operational reports: Includes dashboards and reports needed to provide visibility into day-to-day processes across various departments in the value chain.
 - Data Analytics plays a critical role in modern water utilities by enabling data-driven decision-making, predictive insights, and operational optimization. By analyzing vast amounts of data from SCADA systems, IoT sensors, GIS mapping, customer billing, weather services, and AI models, utilities can improve efficiency, reduce water loss, enhance service reliability, and ensure regulatory compliance. Based on the complexity level of analytics use case, Data Analytics and advanced Data Analytics are segregated into two sub-capabilities:
 - **Analytics:** It generally answers the question “What happened?” using real time and historical data. Key use cases such as self-service analysis, data discovery and search, analytics sandbox that enables use of analytics APIs by third parties and data visualization to generate dashboards to highlight insights from analytics:

- **Self-Service Analytics:** this can enable the users to generate periodic (Daily / Monthly / Annual) or ad hoc reports and analyze the data to generate insights.
 - **Data Discovery and Search:** Analytics systems can generate meaningful insights by searching for select parameters within the Data Platform and then generating insights by analyzing the data based on algorithms. E.g., search and discover SCADA system insights such as pump performance, water pressure levels.
 - **Analytics Sandbox:** Enables external apps including third party apps to integrate with analytics APIs and build solution offerings leveraging the same.
 - **Visualization:** Data visualization tools help in generating intuitive and interactive dashboards for insightful representation of analytics results and trigger actions. E.g., NRW dashboard will visually represent water loss trends due to leakage in pipes by analyzing production vs distribution vs metered water volume, data from flow and pressure sensors.
- **Advanced Analytics:** It generally provides complex insights and generally helps answer the question “Why did it happen” by identifying correlation and patterns in data related to operational failures. Key use cases include:
 - **Customer 360:** Analyses the overall relationship of the customer including satisfaction / happiness rating, sentiment analysis and more based on the customer interaction through various touchpoints.
 - **Mobile / Geo-Spatial Analytics:** this can help in performing a holistic NRW root cause analysis by analyzing geo-spatial data from various sources (e.g., sensors, SCADA, smart meters, satellite images) to determines the root cause non-revenue water (pipeline leakage, theft, or faulty meters)
 - **Demand Forecasting:** Determines the forecasted demand to enable fulfilment of demand-supply gap by taking measures such as changing pumping schedule, storage levels.
 - Other areas of advanced analytics such as Predictive analytics, prescriptive analytics, GIS and geospatial analytics and others. are covered as part of AI platform section hereunder.

Data Management and Governance

Water utilities manage sensitive customer, operational, and financial data, requiring robust governance and security controls. This includes following key capabilities:

- **Master Data Management:** Ensures a single source of truth for customer, GIS master, asset master data and others. Also stores reference data which is used across the system to enable configurability.
- **Data Quality and Management:** This component ensures automated data validation, data cleansing by automated detection and correction. Key capabilities enabled by this component include tracking the data lineage from one system to another for consistency, creating a data catalogue which serves as a centralized repository of all data assets of a water utility ensuring visibility of data across various stakeholders in the organization. Lastly, the data quality management is automated by tracking data quality defects and resolution process.
- **Data Governance:** Governance is enabled by data stewardship which ensure ownership of various data assets and responsibilities of data stewards while managing the dissemination of data assets (reports / dashboards) to various data owners. Data governance is driven by data policies that drives the rules for data security, privacy, and retention.

AI Platform and Operations

The AI Platform and Operations Layer in a water utility enables automation, intelligent decision-making, and predictive analytics to optimize water production, distribution, infrastructure maintenance, and customer service. This layer integrates data, machine learning (ML), and AI-driven automation to support real-time monitoring, predictive insights, and operational efficiencies. Different areas within AI are described below:

- **Predictive Analytics:** Predictive analytics typically answer the question “what is likely to happen?” using AI / ML algorithms. Key use cases include:
 - **Leakage and Pipe Burst Prediction:** Uses AI to forecast which pipelines are most likely to break based on pressure stress, temperature, and material age.
 - **Pump And Asset Failure Prediction:** Uses SCADA sensor data to estimate when a pump or valve might fail.
 - Water demand forecasting predicts future demand based on weather, seasonality, and consumption patterns.
- **Prescriptive Analytics:** This area typically answers the question “What actions should we take?” using **Gen AI (external LLM) Integrations:**
 - **Generate Optimized Pump Schedule:** AI adjusts pumping schedule to optimize costs based on forecasted demand.
 - **Workforce Allocation and Scheduling:** Generate field force schedule based on urgency, location, or workload distribution.
 - **Water Treatment Optimization:** generate chemical dosing including chlorination and filtration rates based on water quality data from sensors.
 - **NRW optimization:** analyze data from various sources to generate actionable insights to optimize losses due to non-revenue water. E.g., SCADA and pressure flow data to detect pressure drops in affected areas, Infrared sensors, and acoustic analysis to detect underground leaks.
- AI agents are virtual assistants / bots that enable users to interact with AI platform and perform various tasks such as initiate customer service request, generate data insights.
- **AI / ML models:** Covers end-to-end processes related to AI/ML model development, Pre-processing of data and training of models, deployment and serving of AI models.
 - **AI / ML Model Development:** Leverage technologies such as Pytorch, tensor flow and others to build, train and optimize AI/ML models for water utilities.
 - **Data Pre-Processing:** Pandas and NumPy can be used for data engineering and preprocessing before loading the data into AI / ML models for training and usage.

- **AI/ML Model Training and Hyperparameter Tuning:** Training AI/ML models requires specialized tools for distributed training and hyperparameter tuning. Pytorch lightning or TensorFlow mirrored strategy can manage multi-GPU training with minimal code. Tools like Optuna and Raytune are used for hyperparameter tuning. Various cloud services like AWS Sagemaker, Google Vortex AI and Azure Machine Learning can also be leveraged for model training and tuning on cloud.
- **AI Model Deployment And Serving:** Various model serving and deployment technologies can be used to serve real-time predictions like Tensorflow serving can be used for deployment of trained Tensorflow based AI/ML models, TorchServe can be used for deployment of PyTorch based models.
- **External LLM integration:** Water utilities can leverage external LLMs like ChatGPT (OpenAI), Gemini (Google), LLaMA (Meta) APIs to process natural language data, generate reports, automate workflows, and improve predictive and prescriptive analytics.

AI Operations covers capabilities such as defining AI guardrails, Prompt operations, AI governance and Responsible AI policies. AI guardrails are established to prevent misinformation and bias from content generated by LLMs. Responsible AI policies and governance mechanisms promote fairness and non-discrimination while AI is used to serve different types of customers. It also ensures transparency, auditability and accountability of predictions made by AI/ML models. AI security is essential to ensure privacy of personally identifiable data such that data elements like payment details and others are not saved by AI models.

3. Core Business Capabilities

The Core Business Capabilities Layer forms the foundation of water utility operations, ensuring the efficient management of water production, distribution, metering, revenue collection, asset lifecycle management, inventory handling, field workforce operations. Additionally, it includes critical support functions within the ERP layer, such as finance, procurement, human resources, governance, and compliance.



Figure 29: Core Business Capabilities

Digital transformation of these core business processes enables utilities to optimize performance, reduce losses, and enhance service delivery.

Production and Distribution

Water production involves the sourcing, treatment, and supply of water to ensure a sustainable and high-quality water supply. Water distribution involves the efficient and equitable delivery of treated water to various types of consumers. Key capabilities include:

- **SCADA Systems for Real-Time Monitoring** – Tracks flow rates, pressure, and water quality metrics.
- **Water Quality Monitoring** – IoT sensors track pH levels, turbidity, and contamination risks. This information is processed and visualized on dashboards to generate meaningful insights.
- **Variable Frequency Drives (VFDs)** – VFDs are centrally controlled and operated electronic devices that control the speed of electric motors by adjusting the frequency and voltage of the power supplied to the motor. In water utilities, VFDs optimize pump performance, reducing energy consumption and wear on equipment.

- **Hydraulic Modeling Systems:** These are computer-based tools used to simulate and analyze the behavior of water distribution systems, wastewater collection systems, and stormwater drainage systems. These systems help the water utility engineers design, operate, and manage their systems more efficiently. The hydraulic modeling system typically has following key components:
 - **Distribution Network Model (Digital Twin):** A digital representation of the water distribution or collection system, including pipes, pumps, valves, and other components.
 - **Hydraulic Engine:** A computational engine that simulates the behavior of the system under various conditions, such as different demand patterns, pipe failures, or pump operations.
- **Production Management:** End to end planning and scheduling of water production to maintain a stable supply to meet the current and forecasted demand.
- **Automated Dosing Systems:** Adjusts chemical treatment based on AI-driven quality assessment on top of the sensor data collected by the RTUs.
- **Programmable Logic Controllers (PLCs):** PLCs are computer-based control systems that monitor and control industrial processes, such as water treatment and pumping systems. PLCs manage pumping
- **Remote Terminal Units (RTUs):** Remote Terminal Units (RTUs) connect the sensors, and other equipment in the field, collecting data and performing control functions. They enable remote monitoring, control, and automation of various processes and systems.

Billing and Collections:

Water distribution involves the efficient and equitable delivery of treated water to various types of consumers. Key capabilities include:

- **Billing and Arrear Management** – Bill generation, tracking of bill and arrears, payment history and reconciliation of bill payments.
- **Payments** – Enabled by banking systems, mobile wallets, and customer portals for flexible payment of bills and arrears.
- **District Metered Area (DMA) Management** – Creates and manages administrative boundaries (called zones) for monitoring, billing, collection, revenue leakage.
- **Revenue Management:** enables water utilities to centrally monitor and manage non-revenue water, analyze the root cause of revenue leakage (e.g., leakage, theft, faulty meters) and take necessary actions to reduce NRW.

Asset Management

It involves tracking, maintaining, and optimizing the performance of infrastructure like pipes, valves, pumps, and treatment plants. Key capabilities include:

- **Asset Data Management:** It provides a centralized data storage for all the structured and unstructured data related to the assets in the utility's network. E.g., asset health data generated by the sensors, location data generated by GIS.
- **Asset Register Management:** – Tracks the condition of the assets across the lifespan of the asset.
- **Asset Design and Build:** This capability enables digital planning, engineering, and construction of new infrastructure. E.g., topographic data to optimize pipeline routes, sourcing of raw materials for design of new assets.
- **Asset Monitoring:** It is focused on continuous tracking of asset health and detecting early signs of failure. This capability will be enabled by analyzing sensor data and can trigger alerts and notifications when the maintenance of assets is due, or signs of wear and tear are detected.
- **Asset Maintenance:** manages end to end planning, scheduling, and recording maintenance activities for various types of assets including breakdowns, repairs, replacements, AMC contracts and others.
- **GIS:** GIS (Geographic Information System) enable asset management by enabling water utilities to visualize, manage, and analyze their assets spatially.

Inventory Management

Effective Inventory Management in a water utility ensures the availability of critical spare parts, chemicals, meters, pumps, pipes, and operational supplies to maintain uninterrupted service delivery.

- **Inventory Management:** Centralized data for all items in the inventory including pipes, pumps, valves, chemicals, spare parts, consumables, and others.
- **Inventory Planning:** forecast demand of inventory and plan procurement budget, optimum stock levels, optimize inventory turnover and automate stock replenishment cycles.
- **Inventory Sourcing:** Streamlines the procurement of spare parts, treatment chemicals, and operational materials by managing the end-to-end sourcing and procurement management process.
- **Contractor Management:** Manages external contractors and third-party service providers overseeing infrastructure repairs, meter installations, and pipeline projects.
- **Storekeeping:** Optimizes the physical storage, retrieval, and distribution of inventory across warehouses and field stores. Key capabilities will include RFID based stock identification, automated warehouse organization, monitoring of warehouse conditions, theft prevention, automated dispatch, and logistics management.

Field Force Management

Field Force Management (FFM) in water utilities ensures efficient task execution, optimized workforce deployment, and real-time tracking of field operations. The core areas of field force management include task management, service delivery management and field force training management.

- **Task Management:** Manages, tracks, and automates various field tasks, including maintenance, meter inspections, new service connections, and customer complaints.
- **Service Delivery Management:** Optimizes workforce planning, scheduling, and customer order management to ensure timely service delivery. Workflow automation ensure the tasks follow the Standard Operating Procedures (SOPs).
- **Field Force Training Management:** Provides field force / technicians with on-demand training, knowledge resources, and operational support.

Enterprise Resource Planning:

The Enterprise Resource Planning (ERP) layer in water utilities provides an integrated, centralized platform to manage support functions such as finance, human resources, procurement, vendor partnerships, and regulatory compliance. Key capabilities include:

- **Human Resource Management:** Manages employee lifecycle from recruitment, payroll, training, performance tracking, transfers, leave and attendance and workforce planning.
- **Finance and Accounting:** Handles budgeting, financial planning, billing, revenue management, expense management, financial reporting, general ledger and more.
- **Supply Chain and Procurement Management:** Ensures timely procurement, inventory optimization, and supplier coordination for essential equipment and materials.
- **Vendor, Contractor, and Partner Management:** Ensures efficient collaboration with external vendors, service providers, and infrastructure contractors.
- **Administrator and Office Management:** Supports administrative operations, ensuring smooth facility management, office logistics, and internal workflows.
 - **Governance, Risk and Compliance:** Ensures regulatory compliance, risk mitigation, and adherence to safety/environmental policies.

4. Infrastructure

The Infrastructure layer includes both physical and digital assets. **Physical Infrastructure** consists of pipes, pumps, and reservoirs that support water distribution and treatment. **Digital Infrastructure** includes IT networks, cloud systems, and cybersecurity tools that enable digital operations and data management.



Figure 30: Infrastructure

A modern water utility leverages **smart meters and IOT sensors** to monitor the water quality, assets and inventory involved in water production and distribution core processes that enables real time monitoring for seamless service delivery. Following are the **key components of digital infrastructure**:

- **Network and Communication:** It ensures real time connectivity across assets and business applications for seamless flow of data. Water devices typically use 4G, 5G or even satellite connectivity in remote locations to establish a network of connected devices.
- **Cloud Management:** a modern utility leverages cloud infrastructure and services for building scalable and reliable platforms across all the layers.
- **IT Facility Management:** A water utility will provide a centralized data center and disaster recovery center to host applications on-premise (or private cloud). This capability involves DC – DR management areas including power, HVAC, data replication, backup, and business continuity planning in the event of a natural disaster.
- **IT Device Management:** this capability enables the water utilities to centrally manage the devices used by the staff to securely access the employee and field-force mobile applications from their mobile devices enabling a BYOD (Bring Your Own Device) mechanism.
- **Backup and Archival:** involves capability to backup and restore the data and archive the historical data to prevent data loss and ensure business continuity.

- **Smart Meters:** Enable automated metering, bill generation and remote monitoring. Also enables demand forecasting by tracking consumption patterns.
- **IoT Sensors and IoT Gateway:** a water utility may use various types of sensors such as flow sensors, pressure sensors, water quality sensors (pH, turbidity), GIS and other devices to enable real time monitoring. An IoT gateway is a device that connects IoT sensors and devices to the internet, enabling data transmission and communication.
- **Fault and Performance Monitoring:** Track and monitor data generated by various devices and systems to monitoring system health and optimize prediction, detection and resolution of issues and incidents.
- **Logging:** Ensures traceability and accountability of various applications, users and even AI models while taking decisions or performing actions on any of the applications.

5. Integration and Data Exchange



Figure 31: Integration and Data Exchange

The Integration Layer in a water utility ensures seamless communication between different IT systems, IoT devices, SCADA, ERP, smart meters, customer portals, and external third-party services. It **acts as the backbone for data exchange, automation, and interoperability**, ensuring that critical business processes run efficiently.

By leveraging API orchestration, event-driven messaging, encryption, and secure data transfer, water utilities can enable real-time monitoring, automated billing, predictive maintenance, and regulatory compliance. Systems that enable integrations include:

- **File Transfer Systems:** systems like Managed File Transfer (MFT) systems facilitate secure file exchanges between internal and external systems supporting multiple file formats such as XML, CSV, Excel, and others.
- **Batch Scheduling:** Automates and schedules recurring batch jobs on predefined schedules for operational events. E.g., a batch job enabled at end-of-month would consolidate meter readings to generate the bill.
- **API Orchestration:** Manages data exchange across multiple systems by coordinating API calls in a secure and scalable manner. Supports various API methods such as REST, SOAP, GraphQL.
- **Event Driven (Pub-Sub) Integration:** Manages event-driven messaging between systems, ensuring real-time data updates and alert notifications. Enables real time data streaming by using technologies such as Kafka, MQTT.
- **Internal API Gateway:** Facilitates secure and optimized communication between internal utility systems (e.g., ERP, SCADA, billing, GIS, IoT). Provides capabilities such as rate limiting and caching to optimize API performance, manages API response time, error rates and communicates using consistent and standardized REST / XML formats.
- **External API Gateway:** Manages secure API integrations with third-party services, government agencies, payment providers, and weather and satellite data sources and others. Provides multi-layer security using OAuth, JWT, and API keys for authentication.
- **Adapters and Connectors:** Enables legacy systems and modern applications to exchange data seamlessly by bridging the gap between legacy databases, IoT networks, and modern APIs and converting data into compatible formats.
- **Encryption and Masking:** Ensures data privacy, regulatory compliance, and secure system interactions. Protects customer records, billing transactions, and SCADA data by providing end-to-end data encryption and hides sensitive customer data to ensure regulatory compliance to global data privacy regulations such as GDPR and others.

6. Security and Identity Management

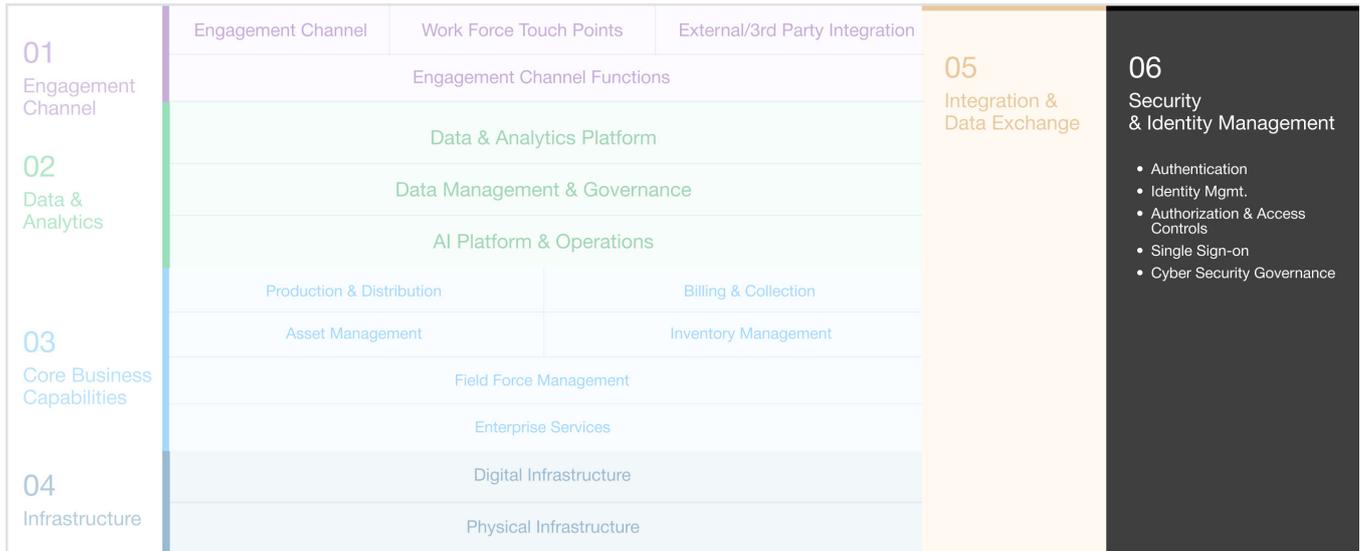


Figure 32: Security and Identity Management

As utilities increase their reliance on digital technologies, securing these systems and managing access becomes imperative. Security in a modern water utility is critical to protect operational technology (OT), IT systems, IoT infrastructure, customer data, and financial transactions from cyber threats, unauthorized access, and compliance risks.

The **Security and Identity Management** layer ensures safe access to critical systems like SCADA, ERP, IoT devices, and customer portals. It includes multi-layered authentication, role-based access, single sign-on, encryption, and cybersecurity governance, enabling utilities to comply with relevant data regulations (e.g., GDPR, ISO 27001, NIST).

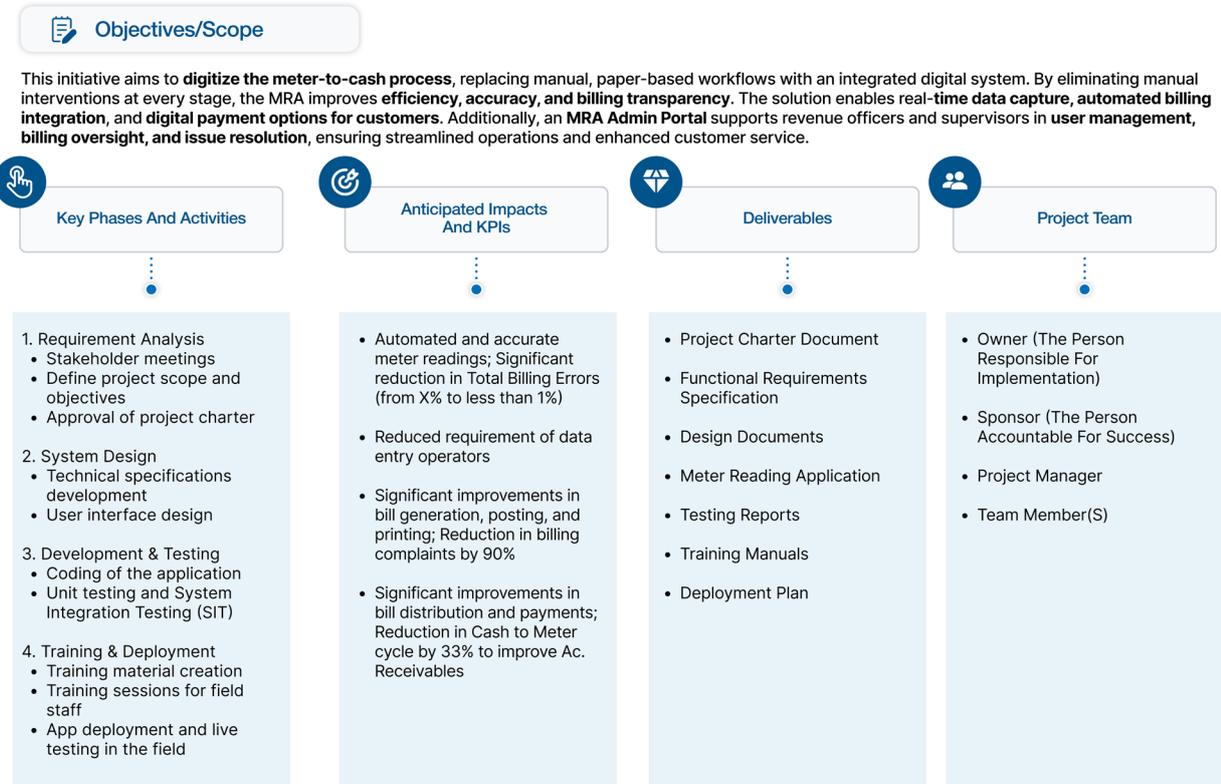
Following are the key capabilities enabled by this layer:

- **Authentication:** Verifies user and system identities before granting access to water utility applications, control systems, and cloud platforms. Also provides capabilities such as multi-factor authentication, federated identity management to prevent unauthorized access.
- **Authorization:** Ensures users and systems only access resources they are authorized for, preventing unauthorized actions. Defined segregation of duties preventing conflicts of interest, and enables role based / attribute-based access control and Privileged access.

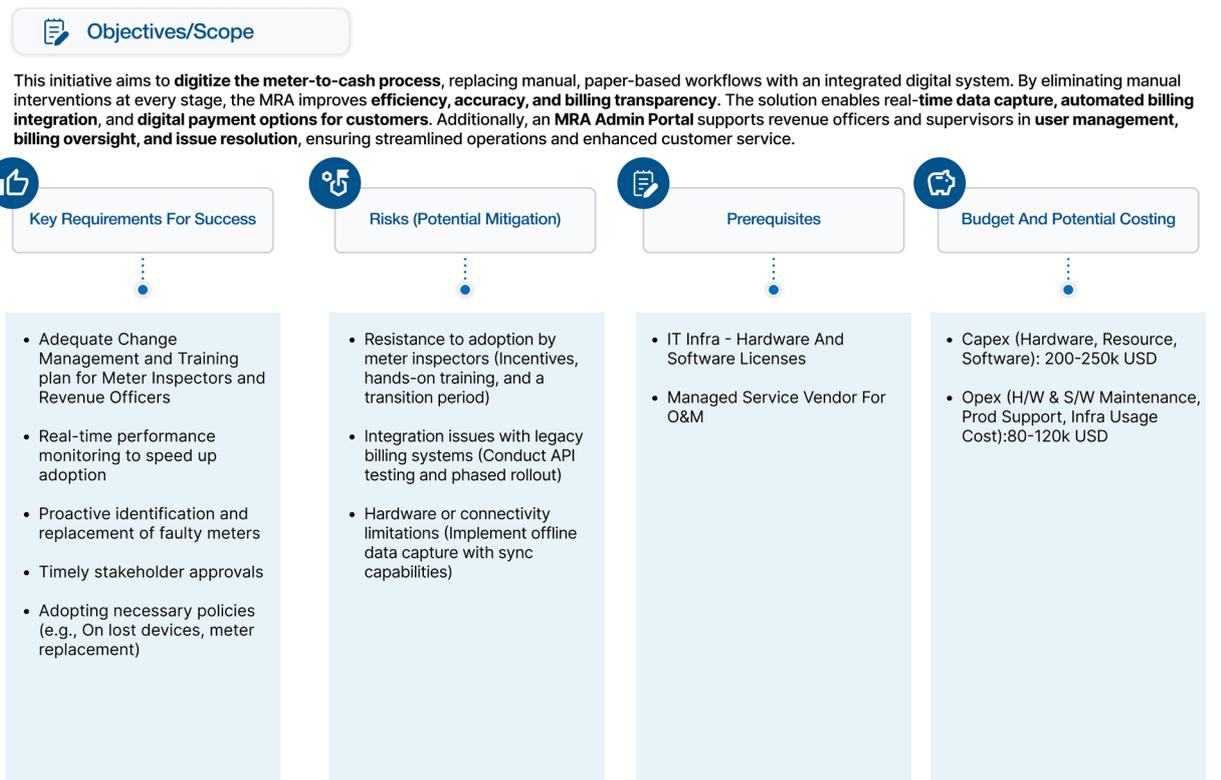
- **Identity Management:** Centralizes user identity management, ensuring secure and controlled access across multiple utility systems. It is enabled by a centralized identity store that captures identity of customers, employees, contractors, third parties and more. and governs their access privileges and roles on the platform.
- **Single-Sign-On:** This capability allows users to log in once and gain access to multiple applications securely, reducing password fatigue and improving security. It is enabled by using standard integration protocols like SAML, OAuth, OpenID Connect.
- **Cyber Security Governance:** Defines policies, compliance standards, and monitoring frameworks to protect water utility infrastructure from cyber threats. Provides various capabilities such as:
 - Security risk assessment continuously scans systems for vulnerabilities, misconfigurations, and security gaps.
 - Adherence to regulatory compliances such as ISO 27001, NIST, GDPR.
 - Incident response and forensics for detection of security lapses.
 - Security awareness and training: Conducts regular employee cybersecurity training with phishing simulations.

Appendix B: Sample Project Charter for a Digitalization Initiative

Sample Project Charter (1/3): Meter Reading App



Sample Project Charter (2/3): Meter Reading App



Sample Project Charter (3/3): Meter Reading App

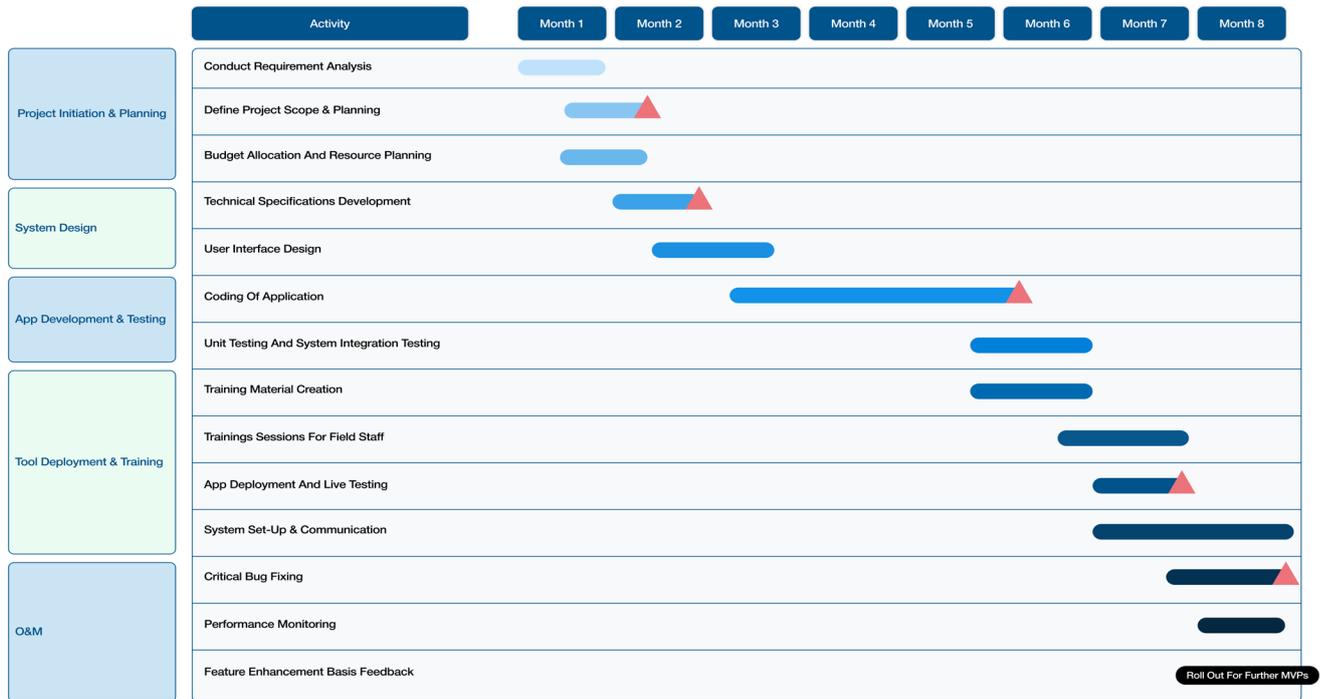


Figure 33: Sample Project Charter

A **Project Charter** serves as a **foundational document** that defines the key aspects of a digitalization initiative, ensuring alignment among stakeholders and providing a structured roadmap for execution. It establishes **clear objectives, expected impacts, key deliverables, success factors, risks, and timelines**. Below is a general description of each element typically found in a project charter:

1. Objective/Scope

Defines the goal of the project and outlines its scope, specifying what the project aims to achieve and the boundaries within which it will operate. Ideally, the objective of the initiative should clearly contribute to delivering against the overall digital transformation objectives.

2. Key Phases and Activities

Defines the major steps in project execution, such as initiation, planning, development, testing, deployment, and closure. This section is typically supported by a Gantt chart, which provides a visual representation of milestones, dependencies, and timelines, ensuring clear tracking of progress and alignment with project goals.

3. Benefit/Impact

Outlines the measurable benefits and key performance indicators (KPIs) that define project success such as reduction in manual effort and operational inefficiencies, improvement in accuracy, compliance, and service delivery, cost savings through optimized resource utilization, increased customer satisfaction and engagement and others.

4. Deliverables

Specifies the tangible outputs that the project will produce, such as software applications, reports, training materials, or operational guidelines. Deliverables should be concrete and measurable, ensuring that all stakeholders have a clear understanding of project outcomes.

5. Project Team

Identifies the key personnel involved in the project, including internal Project Sponsor, Project Owner, Project Manager, and other Team Members. This may be further supplemented by a clear delineation of the roles and responsibilities of each member. Ideally, the owner should play a lead role in drafting the charter and be fully engaged in objective/target setting. The sponsor and owner need to be fully committed to the project.

6. Key Requirements for Success

Defines the critical factors necessary for effective implementation to achieve the anticipated outcomes, which may include change management and user training to drive adoption, real-time performance monitoring to measure impact, stakeholder alignment for approvals and support. If new skills and capabilities are needed to be developed for initiative implementation, they need to be clarified here.

7. Risks and Potential Mitigations

Lists potential challenges that could impact project success, such as data limitations, system integration issues, or resistance to change, along with external factors that may influence project execution.

8. Prerequisites

Describes the necessary conditions and resources required for the project to proceed smoothly, such as infrastructure, technical expertise, and others.

9. Budget and Potential Costing

Estimates the capital and operational expenses. Typically, CAPEX includes implementation resource cost, off-the-shelf software cost, and hardware costs and the OPEX includes ongoing software enhancements/ fixes (AMS), hardware maintenance (ATS), software maintenance (AMC), IT support costs, and cloud subscription costs.

10. Implementation Timelines

Provides an estimated timeline for key phases, including start and end dates, key milestones, and final project completion.

A project charter helps ensure clarity, accountability, and alignment among all stakeholders, guiding the project from initiation to successful completion.

Appendix C: Advancing Construction Management and Operations Through Digital and Data

As highlighted in Section 3.1.2, large capital projects for water utilities, especially in emerging market economies, often experience significant delays, leading to soaring costs, loss of momentum, and delays in essential services reaching citizens. A major contributor to this challenge is the lack of real-time project visibility and coordination, resulting in inefficient resource allocation, fragmented stakeholder communication, procurement bottlenecks, and reactive rather than proactive risk management.

In this report, we explored how a range of digital tools are transforming the management of large capital projects, enabling greater efficiency, risk mitigation, and improved decision-making. These include project management tools (e.g., Primavera P6, MS Project) for structured scheduling and resource allocation, modeling and simulation tools (e.g., Bentley OpenFlows, Autodesk InfraWorks) for engineering design and feasibility analysis, and procurement platforms (e.g., Coupa Procurement, SAP Ariba) for supply chain optimization. One transformative digital solution that is being used to serve as a centralized intelligence hub is the **Digital War Room**, which can generate integrated insights from various models (e.g., risk predictions), site imagery, IoT sensors, GIS-based tracking systems, procurement platforms, and work force planning tools to enhance project visibility and coordination. By providing a comprehensive, real-time view of the entire project lifecycle, Digital War Rooms streamline communication among stakeholders, highlight interdependencies between activities, track remaining work, and suggest proactive measures to de-risk projects and accelerate completion. For example, a large European metro⁶⁵ project facing potential delays in a €1 billion+ infrastructure project implemented a fully integrated Digital War Room, which helped it save €15 million and accelerate completion by eight months through enhanced coordination and efficiency.

Beyond construction management, we also highlighted that the **data captured during the construction phase plays a critical role in the long-term operations and maintenance (O&M) of utility assets**. Structured data collection ensures that essential asset information is available, accessible, and actionable, supporting preventive maintenance, performance optimization, and lifecycle cost reduction. The following table outlines key data types captured during construction, along with how they are collected, stored, and used to support effective utility operations and asset health management.

⁶⁵BCG Case Experience

Data Type	Data Collection	Data Storage	Data Use Cases
<p>Asset Specifications & Equipment Data (e.g., equipment type, installation date, technical parameters, warranty info, maintenance schedule, pipeline maps, station locations)</p>	<p>Captured via Radio-Frequency Identification (RFID), QR codes, barcodes, manual entry in ERP systems, IoT-enabled asset tracking, GPS field surveys, drone imaging, LiDAR scanning, and remote sensing tools</p>	<p>Stored in a Fixed Asset Register (FAR) within ERP system and EAM platforms (e.g. IBM Maximo, Infor EAM) or as a standalone system. GIS data is stored in GIS databases and spatial data management systems (e.g., ESRI ArcGIS Server, Hexagon GIS)</p>	<p>Used for maintenance planning, lifecycle tracking, asset replacement scheduling, and spatial analysis for asset location tracking, pipeline route optimization, and underground asset mapping</p>
<p>As-Built Drawings, Redline Markups, and Visual Documentation (e.g., finalized layouts, redline markups, pipeline routing diagrams, valve locations, revisions to original design plans)</p>	<p>Field engineer updates, Building Information Modeling (BIM) tools (e.g. Autodesk Revit, Bentley OpenPlant), and, 360-degree cameras, mobile field apps, drone/LiDAR scanning</p>	<p>Stored in cloud-based document management systems and Digital Twin platforms. Images and visual records are archived in digital asset management systems during handover</p>	<p>Used for troubleshooting, system modifications, infrastructure expansion planning, workforce training, AR/VR safety simulations</p>
<p>Project Management and Quality Testing Data (e.g., material test results, welding and joint inspections, pressure testing, structural integrity assessments, incident reports, execution logs for claims/dispute resolution)</p>	<p>Project Management Tools (e.g., Primavera P6, MS Project) Digital Quality Assurance (QA) inspections, mobile-based field data entry, sensor-based monitoring for material testing. Tools like Computerized Maintenance Management Systems (CMMS) mobile apps (e.g., Fiix, eMaint), digital QA forms</p>	<p>Stored in a QA/QC (Quality Assurance/ Quality Control) database within CMMS platforms, project management systems, and Digital QA systems. Project Mgmt. tool data is stored in cloud-based project management systems and exported to document control databases at handover</p>	<p>Used for regulatory compliance, quality assurance, maintenance scheduling, claim settlements, dispute resolution, and referencing past project execution for planning future projects</p>

Glossary

Acronym	Elaboration
AI	Artificial Intelligence
AMC	Automated Metering Control
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AMS	Asset Management System
API	Application Programming Interface
ATS	Advanced Telemetry System
AWS	Amazon Web Services
BCG	Boston Consulting Group
BCR	Benefit-Cost Ratio
BEL	Bharat Electronics Limited
BENTLEY	Bentley Systems
BI	Business Intelligence
BYOD	Bring Your Own Device
CAPEX	Capital Expenditure
CDC	Change Data Capture
CRM	Customer Relationship Management
CSP	Cloud Service Provider
CSV	Comma-Separated Values
DC	Data Center
DERP	Disaster and Emergency Response Platform
DMA	District Metered Area
DR	Disaster Recovery
EBIT	Earnings Before Interest and Taxes
EDW	Enterprise Data Warehouse
ELT	Extract, Load, Transform
EPANET	Environmental Protection Agency Network
ERP	Enterprise Resource Planning

ESG	Environmental, Social, and Governance
ETL	Extract, Transform, Load
EUR	Euro
FFM	Flood Forecasting and Management
FY	Fiscal Year
GCP	Google Cloud Platform
GDPR	General Data Protection Regulation
GE	General Electric
GESAB	GESAB is a company that specializes in the design, manufacture, and installation of control rooms, control centers, and technical furniture for various industries.
GHG	Greenhouse Gas Emissions
GIS	Geographic Information System
GPS	Global Positioning System
GPT	Generative Pre-trained Transformer
GPU	Graphics Processing Unit
HANA	High-Performance Analytics for Real-Time Decision-Making
HQ	Headquarters
HR	Human Resources
HVAC	Heating, Ventilation, and Air Conditioning
ICCC	Integrated Command and Control Center
ID	Identity Management
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
IVR	Interactive Voice Response
JICA	Japan International Cooperation Agency
JWT	JSON Web Token
KPI	Key Performance Indicator
KSF	Key Success Factors
LLM	Large Language Model
MDM	Master Data Management
MFT	Managed File Transfer

MI	Meter Inspector
MIS	Management Information System
ML	Machine Learning
MLD	Million Liters per Day
MOD	Metering Operations & Data Management.
MQTT	Message Queuing Telemetry Transport
MRA	Meter Reading App
NGO	Non-Governmental Organization
NIST	National Institute of Standards and Technology
NRW	Non-Revenue Water
OAUTH	Open Authorization
OCR	Optical Character Recognition
ODS	Operational Data Store
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
ORACLE	Oracle Corporation
OT	Operational Technology
PLC	Programmable Logic Controller
PPP	Public-Private Partnership
QGIS	Quantum Geographic Information System
GRAPHQL	Query Language
RDBMS	Relational Database Management System
REST	Representational State Transfer
RFID	Radio-Frequency Identification
RO	Reverse Osmosis
RTU	Remote Terminal Unit
SAML	Security Assertion Markup Language
SAP	SAP SE is a technology provider for ERP systems.
SAR	Spatial Asset Registry
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goals
SIEMENS	Siemens Corporation
SIMATIC	SCADA product built by SIEMENS

SIMATICS	SCADA product built by SIEMENS
SINAMICS	Variable Frequency Drive product built by SIEMENS
SITRANS	Remote Terminal Unit for Sensors built by SIEMENS
SIWA	GIS system built by SIEMENS
SMS	Short Message Service
SOAP	Simple Object Access Protocol
SOP	Standard Operating Procedures
SRM	Supplier Relationship Management
TMO	Transformation Management Office
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
USD	United States Dollar
VFD	Variable Frequency Drive
WHO	World Health Organization
WPDX	Water Point Data Exchange
WTP	Water Treatment Plant
WWF	World Wildlife Fund
XML	Extensible Markup Language
YSI	Xylem YSI is leading provider of water quality monitoring solutions

