POSITION PAPER

INTEGRATING ICT IN THE CARIBBEAN WATER AND SANITATION SECTOR: IMPACTS, OPPORTUNITIES AND LIMITATIONS

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This Position Paper was prepared by Kevon Rhiney.
It is intended to galvanise discussion within the GWP-C network and the larger water and development community.

www.gwp-caribbean.org

ABOUT GLOBAL WATER PARTNERSHIP-CARIBBEAN

The vision of the Global Water Partnership-Caribbean (GWP-C) is for a water secure Caribbean. Our mission is to support Caribbean countries in the sustainable management of their water resources at the community, national and regional level.

GWP-C is 1 of 13 Regional Water Partnerships of the Global Water Partnership (GWP). It was established in 2004 to foster the application of Integrated Water Resources Management (IWRM) in the Caribbean region. IWRM is the coordinated development and management of water, land, and related resources, in order to maximise economic and social welfare without compromising the sustainability of ecosystems and the environment.

Any organisation with an interest in water sustainability in the region, can become a GWP-C Partner. GWP-C currently has over 100 partners in more than 20 Caribbean countries. These include water management agencies, water user associations, private water management agencies, government institutions, academic and research institutions, private sector companies, non-governmental organisations, community-based organisations, civil society organisations, youth organisations, regional agencies, consultancy firms, among others.

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INTRODUCTION

This report forms part of a series of technical papers being produced by the Global Water Partnership-Caribbean (GWP-C) to highlight issues of key concern in the Caribbean water and sanitation sector. This technical paper focuses on opportunities and progress made in the integration of information and communication technologies (ICTs) in water and sanitation services and is intended to provide a platform for exploring opportunities for advancing investment, policy mobilization and research around ICT solutions to achieving regional water security. From a policy standpoint, water and sanitation comprise a number of critically interrelated components which impact human development and wellbeing[1]. Having access to safe drinking water and sanitation is crucial to preventing the spread of water-borne and infectious diseases, supporting global food and nutrition security goals, ensuring the proper functioning of societal institutions (i.e., schools, hospitals, businesses, and governmental bodies) and enabling the full participation of all members of society including traditionally marginalized groups such as women and indigenous peoples.

Water security is seen increasingly as an integral part of human security and central to the achievement of other human rights such as the right to good health, to education, food and nutrition security, and to adequate housing. Thus, adequate access to safe drinking water and provision of adequate sanitation at an affordable price is necessary for an individual to lead a healthy, dignified, and productive life[2]. The 2015 adoption of the 2030 Agenda for Sustainable Development and the Sustainable Development Goal 6 (SDG 6) – the goal of ensuring the availability and sustainable management of water and sanitation for all by 2030 – in particular, means that countries must deliberately devise inclusive and effective strategies to promote, measure and evaluate progress on effective access to services such as safe drinking water and sanitation as part of actions to develop holistic and social protection systems.

Achieving SDG 6 has implications for the entire 2030 Agenda (UN-Water 2021), given the centrality of water to human and planetary health. This goal goes beyond providing universal water and sanitation services, to cover the entire hydrological cycle and the sustenance of vital

[1] Human development is defined as the process of enlarging people's freedoms and opportunities and improving their wellbeing. Human development is related but distinct from economic development; the latter being traditionally associated with processes of economic growth, increases in country-level GDP and national income, and market productivity. Building on traditions and discourses rooted in entitlement theory and capability approach (see, for example, Amartya Sen's seminal work *Development as Freedom),* human development involves the real freedom ordinary people have to live a healthy, safe and prosperous life.

[2] This forms part of the UN resolution on the right to water. In 2010, the UN General Assembly adopted *Resolution 64/292*, formally recognizing "the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights". See link: https://www.un.org/waterforlifedecade/human_right_to_water.shtml

planetary life support systems. This draws attention to the complex interconnections between human and natural systems in a rapidly changing world. How we source, store, consume and conserve water have clear implications for the sustenance of freshwater resources and the preservation of vital ecosystem services. At the same time, human-induced and environmental changes at the global, regional, and local scale can determine ecosystem health and function, which will in turn determine the quantity and quality of freshwater available for societal use. Changes in regional climates will result in increased water scarcity in some regions for instance, with dire consequences across all sectors of society.

These all point to the need for a balanced, evidence-based, and integrated approach to water resources management. Having access to credible and timely water and sanitation data is vital to shaping policy, enhancing decision-making processes, reviewing and evaluation of response measures, and priority setting for allocation of resources. Improving the evidence base will lead to more robust and transparent resource governance and regulatory systems through increasing accountability and providing the basis for more targeted investments and interventions to ensure more efficient service delivery and implementation. The integration of ICT must form a core component of these efforts if we are to overcome existing gaps in institutional and human capacity, particularly at the municipal level, that is usually impacted by resource shortages, limited technical capacity, and outdated infrastructure and governance models. Leveraging new and emerging forms of technologies will transform the ways we generate, validate and exchange data and information on water and sanitation. This is particularly relevant for the Caribbean that suffers from aging equipment and water supply infrastructure, high rates of non-revenue water, limited financial resources, high energy and operating costs, and growing threats to existing freshwater resources from a changing climate. The promotion of integrated water resources management efforts based on ICT adoption, will go a far way in improving efficiency and building resilience in the regional water and sanitation sector.

The remainder of the report will explore opportunities for integrating ICT in regional water and sanitation services. The report is organized in three main sections. The following section sets up the context and rationale for integrating ICT in a rapidly changing world. This includes a brief description of what is meant by ICT and how it links into a wider technological revolution that is fundamentally transforming the way data and information are now being generated, stored, communicated, and utilized. Next, several case studies of ICT adoption in the water and sanitation sector are presented. Case studies will be drawn from the Caribbean as well as internationally, to highlight innovations in the application and integration of ICT across a range of examples ranging from water provision and management, early warning systems (knowledge sharing and data dissemination) to service monitoring and evaluation. The report will also point to possible lessons, critical weaknesses, and challenges for ICT adoption where relevant. The report concludes with a summary of key messages and lessons learned for ICT and water practitioners in the Caribbean. The aim is to introduce interested readers to the range of possibilities that exist for integrating ICTs in the water and sanitation sector. It is our hope that the information and case studies presented in this report will provide the necessary food for thought to stimulate further discussion around an extremely important topic, while highlighting the very real and urgent water challenges confronting us within the context of the broader development aspirations of the Caribbean.

INTEGRATING ICT AND WATER IN A CHANGING WORLD

Information and communications technology (ICT) is the infrastructure and components that enable modern computing and digital technologies. While there is no single, universal definition of ICT, the term is generally accepted to mean all devices, networking components, applications and systems that are combined to allow people and organizations to interact in the digital world (Figure 1). Information and communication technologies (ICTs) are therefore a diverse set of technological tools and resources used to generate, transmit, store, create, and exchange information. These technological tools and resources include telecommunication technologies such as the satellite, the cable, mobile telephony, as well as digital technologies such as computers and the internet (websites, blogs, and emails), live broadcasting technologies (radio, television, and webcasting), record broadcasting technologies (podcasting, audio and storage devices) among, others.

Figure 1: Components of ICT

Although ICT is often considered an extended synonym for information technology (IT), its scope is, in some ways, broader. ICT is often used to describe the convergence and integration of several technologies, and the use of common transmission lines carrying very diverse data and communication types and formats. In computing, information technology infrastructure is composed of physical and virtual resources that support the flow, storage, processing, and analysis of data. An ICT system comprises both internet-enabled networks as well as mobile technologies powered by wireless networks. It also includes antiquated technologies, such as landline telephones, radio, and television broadcast – all of which are still widely used today alongside cutting-edge ICT innovations such as artificial intelligence and robotics.

These more recent ICT innovations represent both a quantitative and qualitative shift in computing and digital technologies which are transforming how people work, digest and exchange information, interact with each other, and navigate their daily lives in the digital age. This new generation of technology (ranging from smart phone applications and digital cloud technologies to AIs and robotics) are drastically altering and revolutionizing all aspects of the human experience with advanced AIs and robotics doing many tasks once handled by humans[3]. Today robots powered by advanced AI technology can answer phone calls and can often more quickly and efficiently handle customers' requests for services.

What is being increasingly regarded, at least in some quarters, as the Fourth Industrial Revolution, is underpinned by broad shifts in society, as individuals are moving *en masse* from personal, face-to-face interactions to ones in the virtual/digital space. This shift has both accelerated and intensified in recent years, especially due to the disruptions brought on by the ongoing COVID-19 pandemic that have seen many businesses and organizations shifting to flexible work-at-home models and capitalizing on remote online platforms to conduct their daily operations. ICT-enabled innovations such as automated business processes and online shopping platforms have not only helped to reduce costs for businesses but have given customers more choices in how they shop, communicate, and interact with service providers. The recent turn to big data where organizations are tapping into vast amounts of data generated by ICT to gain insights and market intelligence to drive innovations in new and existing products and services (including telebanking, telemedicine, and targeted advertisements via social media platforms).

Despite the immense progress made in advancing digital and computing technologies, ICT penetration is highly uneven on the global scale – a phenomenon known as the digital divide. Wealthier countries enjoy far greater access to information technologies and thus have a greater capacity to take advantage of the ongoing digital transformation and the numerous opportunities and benefits derived from ICT applications. According to a 2016 World Bank Study, for instance, in 2016, more than three quarters of people worldwide had access to a cellphone. However, internet access through either mobile or fixed Broadband remains prohibitively expensive in many countries due to a lack of ICT infrastructure. The same study by the World Bank also estimated that more than 4 billion people out of a global population of 7.4 billion, do not have access to the internet. The vast majority of these people reside in the developing world, and often live in remote and vulnerable communities. Additionally, it estimated that only 1.1 billion people worldwide have access to high-speed internet.

[3] Artificial Intelligence (AI) is a term used to describe the theory and development of computer systems that can perform tasks normally requiring human intelligence. Examples of AI-type systems include various expert systems, speech recognition and systems used for financial trading.

Table 1: Key Targets for SDG 6 and Level of Progress

SDG 6	**Ensure Availability and Sustainable Management of Water and Sanitation for All**		
Global Target	Global Indicator	# of countries with data	Latest Status
6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all (100%).	6.1.1 Proportion of population using safely managed drinking water services	117	71% (2017)
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all (100%) and end open defecation (0%), paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Proportion of population using safely managed sanitation services	96	45% (2017)
	6.2.2 Proportion of population with a handwashing facility with soap and water available at home	78	60% (2017)
6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater (-50%) and substantially increasing recycling and safe reuse globally	6.3.1 Proportion of domestic wastewater flow safely treated.	75	---% (2015)
	6.3.2 Proportion of industrial wastewater flow safely treated	2	---% (2017)
	6.3.3 Proportion of bodies of water with good ambient water quality	89	---% (2020)
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time	88	23.4 USD /m3 (2017)
	6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	178	17.3% (2017)
6.5 By 2030, implement integrated water resources management at all levels (100%), including through transboundary cooperation as appropriate.	6.5.1 Degree of integrated water resources management implementation (0-100%)	187	54% (2020)

	6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation	87 (out of 153 sharing transboundary waters)	59% (2020)
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	6.6.1 Proportion of river basins showing high surface water extent changes	185	21% (2020)

Source: UN-Water (2021) Summary Progress Report

There is therefore an urgent need to bridge this digital divide through driving investment in ICT innovations and applications and transitioning towards knowledge societies. In fact, the 2030 Sustainable Development Agenda recognizes the need to increase global access to ICTs as fundamental to the successful implementation of all Sustainable Development Goals (SDGs). ICTs can foster international and regional cooperation and coordination, promoting technology transfer and capacity building, optimizing value chains, and improving efficiencies in energy and resource management, strengthening multi-stakeholder partnerships, and enabling data monitoring and accountability.

The adoption and integration of ICTs assume even greater importance for the water and sanitation sector, since from all indication, the world is not on track to achieve any of the targets for SDG 6 by 2030. As seen in Table 1, the current rate of progress is well below what is needed to meet global targets in several areas. Added to this, significant data gaps exist across global indicators which make monitoring overall progress in these areas impossible. The average UN Member State has data for about two thirds of the global indicators for SDG 6 while some 38 UN Member States have data on less than half of the indicators (UN-Water 2021). These data gaps reflect limitations in technical capacity and financial resources at the national and sub-national levels. Lack of monitoring infrastructure, lack of data management systems, and limited institutional and technological capacity present significant barriers for accelerating progress and action on SDG 6 monitoring and implementation. Adopting ICTs could therefore play a crucial and cost-effective role in addressing these multiple and intersecting challenges[4].

[4] In fact, several global agencies have resorted to using remote sensing technologies coupled with data analytics to provide data on SDG indicators which many individual governments do not have the capacity to generate if they relied on traditional methods of data collection. An example of this is what UNEP is doing for SDG 6.6.1 data, through the Freshwater Ecosystem Explorer platform. See link: https://www.sdg661.app/

THE GLOBAL CONTEXT

Today, we are facing unprecedented challenges in ensuring that everyone has access to sustainably managed water and sanitation services. Although advances made under the earlier Millennium Development Goals (MDGs), which expired in 2015, resulted in increased access for many, there remains a lot more work to be done. And as aforementioned, even while we are making steady progress in meeting some key SDG targets by 2030, recent reports from the UN indicate that the world is off track to achieve SDG 6 (see Table 1 and Figure 2). Presently, more than 2 billion people lack access to adequate sanitation facilities, 1.8 billion people use a contaminated source of drinking water and over 840,000 people die every year from preventable water-borne diseases[5]. It is projected that by 2030 the global demand for water will grow by 50% and water resources worldwide will be subjected to the more and more threat from anthropogenic climate change.

Amidst these growing challenges in water, sanitation, and hygiene (WASH), information and communication technologies (ICTs) are fast becoming an important means of transforming the management of water resources globally and may be instrumental in the achievement of the United Nations' Sustainable Development Goal (SDG) for clean water and sanitation (SDG 6).When applied to the global water and sanitation sector, ICTs are already being mobilized to offer a variety of innovative solutions for sustainably managing water resources. Smart water management (SWM) systems are being applied in a wide variety of development initiatives worldwide to monitor and manage water and sanitation infrastructure and services. Smart water systems use ICT and real-time data and responses as an integral part of the solution for water management challenges. The application of smart systems in water management is wide and spans the entire breadth of the water supply chain, ranging from supporting water utilities to better gather and more accurately monitor and manage water losses to equipping consumers with better more efficient ways of reporting water quality or quantity issues as they arise.

[5] WHO/UNICEF Joint Monitoring Program for Water Supply's (JMP) 2017 Report. Available at: https://washdata.org/sites/default/files/documents/reports/2018-07/JMP-2017-annual-report.pdf

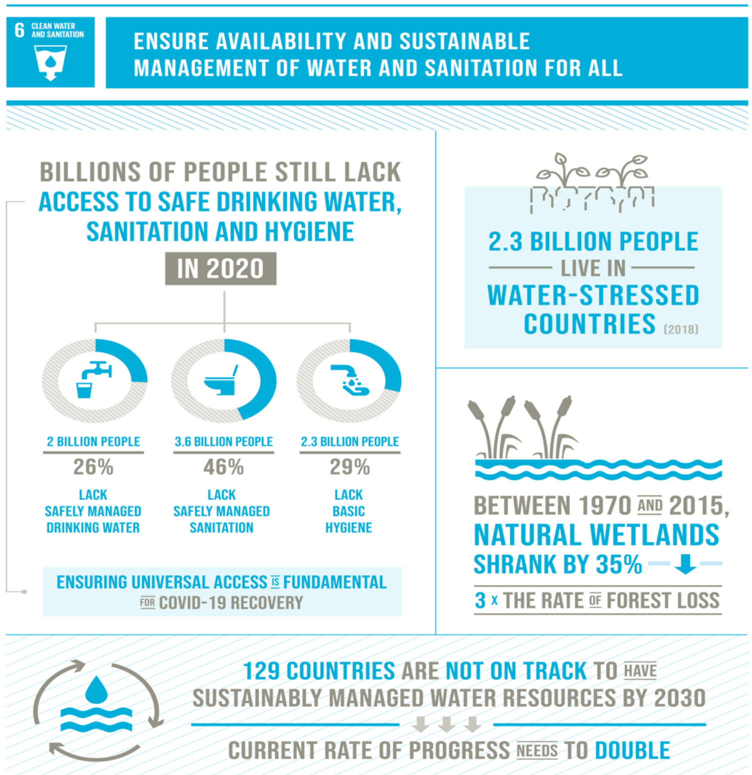

Figure 2: Current Rate of Progress Towards Meeting SDG 6 Targets

Source: The Sustainable Development Goals Report 2021. Available at: https://unstats.un.org/sdgs/report/2021

By applying SWM infrastructure such as sensors, smart meters, monitors, GIS and satellite mapping, and other data sharing tools to water management, real-time solutions can be implemented, and broader networks can work together to reduce existing water management challenges. In Somalia, satellite remote sensing technologies are being used to accurately monitor groundwater quality. Real time monitoring of sanitation status/infrastructure in Kenya is allowing small service providers and customers in urban informal settlements using apps and their mobile phones to alert when pit-emptying services are required. And online data collection in South Africa by community-based NGOs is being applied to monitor and forecast river water levels and to identify new sources of freshwater. And lastly, in Holon municipality in Israel, the sewage system was plagued with problems such as frequent blockages and overflows. By installing gauging devices equipped with sensors, the municipality was better able to manage its sewer systems and now receives reliable information to monitor its sewer system using a web platform and sends alerts via short message service (SMS) messages when the level reaches low/high limits.

These advanced monitoring technologies have proven to be particularly effective in enhancing planning and management, especially during cycles of drought and flooding. For instance, innovations in sensor technology are being used to monitor water usage and leakage in real time, which enhances the management of scarce water resources. Smart automated irrigation systems are now being used to provide optimal water and other nutrients to crops based on real time weather and soil data. Traditional irrigation timers are being replaced with cloud-based smart control applications to maintain plant health with the least amount of water possible and to minimize water waste. There is also increasing interest in the use of 'bots' in water systems to detect and locate leakages in piping systems or changes in water pressure and chemistry. These innovations have clear implications for advancing efforts around climate change adaptation and building resilience in climate-sensitive industries such as agriculture. As water is an increasingly scarce resource, efforts to limit, recycle and treat wastewater will be key to sustainable management.

THE CARIBBEAN CONTEXT

Water remains one of the most important natural resources for the Caribbean and is a key determinant of social and economic development. From a policy standpoint, water is key to alleviating poverty, securing human health and wellbeing, and stimulating economic growth. Water is also pivotal to advancing food security goals through sustaining agriculture and is critical to energy security and industrial development for several states in the region.

The regional water sector is plagued with a range of intersecting challenges posing several development and health risks. Among the main obstacles hindering optimal management of regional water resources are governance, infrastructure, and wastewater management. Each of these impacts the sector in different ways leading to a range of resource management issues including high non-revenue water (see Figure 3), energy inefficiency, reduced water availability, water pollution and poor conservation practices at both the watershed level and in the use of resource.

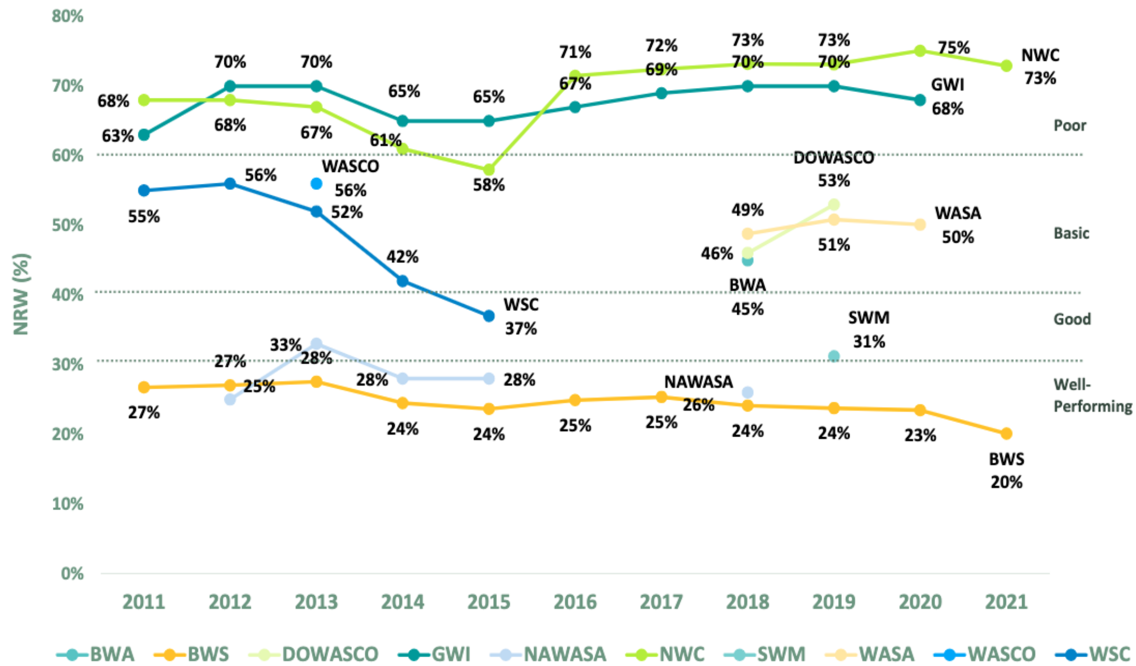

Figure 3: Percentage NRW for Water Utilities from 2011-2021

Source: IDB Caribbean Water Study (2021); see link

In terms of governance, the regional water sector suffers from weak regulation and enforcement, which impacts the ability of national water regulatory bodies and utilities to effectively manage and preserve freshwater resources. Weak regulation and enforcement largely arise from shortages in funding and other resources, inappropriate redress mechanisms and lack of political transparency and accountability. Additionally, in most countries, different agencies are usually responsible for different components of the sector (including source water protection, potable water distribution, sewerage, rural irrigation etc.) which can create institutional silos and bottlenecks.

The Caribbean also suffers from uneven networked coverage and ageing infrastructure which impacts water service delivery. While piped water coverage is relatively high for the region (with countries like Barbados, Bahamas, Saint Lucia, Trinidad & Tobago having national piped water coverage above 90%), rural areas often lag behind urban areas in terms of water coverage (see, for example, IDB Water Study 2021). This is compounded by an ageing water infrastructure that impedes the optimal use and management of this vital natural resource. Old and dilapidated water infrastructure has also resulted in significant levels of water leakage, reaching as high as 70% in some instances. Over the years, regional authorities have focus instead on network expansion rather than on network upgrade, maintenance, and rehabilitation. Furthermore, having high piped water coverage does not necessarily translate into improved service delivery (Lester and Rhiney 2018). Added to this, information on service quality for the

Caribbean is generally lacking. A recent IDB Water Study (2021) indicated that most of the water utilities included in its regional benchmark assessment did not have information on key parameters for measuring and tracking quality of service delivery (including reliability, continuity and responsiveness of the services provided by water utilities to customers). Which indicates that this is an area that requires urgent attention.

The future sustainability of the water sector will be dependent on changes in population demographics and distribution, economic trends, and industry. The impacts of these changes are likely to be compounded under a changing climate that could very well see a reduction in freshwater availability throughout much of the Caribbean (Taylor et al., 2018). Over the past three decades the issue of climate change has assumed increasing importance in dialogue on sustainable development imperatives for the Caribbean, especially regarding concerns around water availability and management (Cashman, 2013; Quarless, 2015). More variable rainfall means much greater uncertainty for people, especially smallholder farmers and already underserved communities. Groundwater, reservoir levels and water resources can be depleted where the climate is getting drier, posing serious threat to human wellbeing and livelihoods. And in all these different situations, it is often the poorest and most vulnerable communities who are hardest hit and least able to cope.

According to the recently published Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), small islands are disproportionately vulnerable to the effects of climate change and the Caribbean region is likely to be severely impacted under a warmer and drier climate (IPCC, 2018). Rising sea levels, higher surface temperatures and changes in rainfall patterns will pose a clear threat to existing freshwater resources, with low-lying coastal communities being amongst the most vulnerable to the impacts of saltwater intrusion. With an average increase of 3.6 mm per year between 1993-2020, the mean sea level in the Caribbean has been rising at a slightly higher rate than the global average (3.3 mm/year). This trend is projected to continue throughout this century regardless of emission scenario, which will negatively impact coastal aquifers. Reductions in water availability compounded by higher temperatures will impact agricultural and livestock productivity due to increases in heat and water stress. Changes in hurricane activity will also pose a threat to water availability and management through impacts on infrastructure and disruptions in water supply.

These impacts are likely to be unevenly felt across the Caribbean with small low-lying coral islands like Antigua and Barbuda and Barbados expected to be amongst the worse impacted by rising sea levels, and industries like agriculture projected to be severely affected by changes in rainfall totals and distribution. Both surface and groundwater sources will be negatively impacted. Drought conditions and declining rainfall totals will result in increased water extraction from aquifers and exploitation of surface water bodies and reservoirs, eventually affecting freshwater availability and quality. With regards to groundwater, anticipated changes in rainfall intensity due to climate change could reduce groundwater recharge during periods of extremely heavy rainfall since much of this water dissipates through surface runoff. In the case of surface water bodies, climate change will induce higher evapotranspiration rates from surface reservoirs due to higher temperatures, thus increasing losses from land-based systems.

Addressing these challenges will require systematic improvements in the ways we manage available freshwater resources. This requires strengthening the capacity of regional regulatory bodies and utilities to collect, collate, analyze, and interpret data needed to better monitor water resource use and management. This includes information on access to potable water and sanitation, water meter data to show consumption patterns and trends, service quality, and operating efficiency to name some. The integration of ICT in the water sector could offer an effective solution to these impending challenges. ICT can help make informed policy decisions. The timely collection and dissemination of data could enhance efficiency and reduce the risk of wastages. Often times, technologies are adopted without taking national infrastructure fully into account, and supporting data is not always adequate or available, resulting in the under- or over-utilization of existing infrastructure. Yet, ICT remains peripheral to water resource management in the region with huge disparities between countries. Countries such as Antigua and Barbuda, the Dominican Republic, Jamaica and Trinidad and Tobago lead in penetration of mobile devices and, in general, in the use of technology for e-government, health and education services. At the other end of the scale, Haiti, Cuba, and Guyana still struggle with scarce penetration rates of services, monopolies, and excessive regulation. And even in cases of high mobile phone penetration, having access to and use of ICT-enabled mobile devices may be limited.

There is however huge potential in integrating ICT in the regional water sector. While the costs of services (particularly related to internet services and smart phone applications) are comparatively much higher than those in higher income countries like the OECD, there has been a steady growth in ICT penetration at the national scale in most countries across the Caribbean, and this is expected to expand to currently underserved rural areas. In some ways, the ongoing COVID-19 pandemic has revealed the urgent need among regional governments to prioritize investments in ICTs, particularly with regards to enhancing internet connectivity, across all sectors including education, health, trade and commerce, agriculture, and water. The use of ICT-related applications for data analysis, management, information, and knowledge sharing, as well as decision support systems, appear to be a logical and appropriate step towards building resilience (in terms of efficiency and improved management) in the regional water sector.

There are already a few good examples in the region where ICTs are being used to facilitate knowledge and information sharing in the water sector[6]. The Caribbean Institute of Meteorology and Hydrology has spearheaded the CariCOF Drought Outlook which is an early warning tool that identifies seasonal trends in drought across the Caribbean basin (CIMH et al. 2020). The

[6] There has been a number of recent publications around enhancing climate services in the Caribbean that might be useful to consider here as well. See for example, Gerlak et al. (2018), Guido et al. (2016) and Mahon et al. (2021)

Outlook includes an overview of shorter- and longer-term trends in map and textual formats. At the national scale, a number of water utilities have been utilizing smart water infrastructure technologies (SWIT) such as smart metering, remote water quality monitoring and remote leakage detection to improve efficiency across the sector. These examples will be expanded on later in the report.

Overall, these point to a positive outlook for the region with several innovations taking root at the regional and national levels. Learning from these initiatives will offer useful insights for policy formulation, priority setting and program intervention, and will become increasingly important as we strive to achieve key sustainable development targets over the short and medium term.

UNLOCKING THE POTENTIAL OF ICT TO IMPROVE WATER AND SANITATION SERVICES

Building on the previous section, we now shift attention to explore some recent advances and innovations in the water and sanitation sector, drawing on a few real-world examples of ICT adoption and application. The intention is to demonstrate, in real terms, the various ways ICT can aid in transforming water service delivery and management in the Caribbean. The case studies presented demonstrate multiple ways ICT can be used to enhance and radically transform the ways water and sanitation utilities are responding to customers' needs, ensuring compliance with regulations, optimizing performance, and ensuring efficient and reliable services.

Examples are drawn from the Caribbean as well as internationally. While these case studies are not exhaustive, and in no way cover the range of ICT applications that exist, they do highlight several innovations in the ways ICT is currently being used to transform the water and sanitation sector. The examples range from the use of artificial intelligence (AI) and bots to enhance water treatment and distribution operations, to innovative applications of remote mapping and forecasting technologies, and implementing smart technologies and micro-sensors to allow for the real-time monitoring of water consumption and sanitation infrastructure status. These include a variety of management applications as well, such as the use of management information systems to help monitor and optimize service delivery. Where possible, attention is paid to how ICT is being used to generate, transmit and streamline water and sanitation data. As illustrated in each of these case studies, these initiatives require strong enabling policy environments and the cultivation of strategic partnerships spanning all levels of government, the private sector, NGO and civil society groups and local communities.

AUTOMATED NETWORK ASSESSMENT USING AI AND ROBOTICS TECHNOLOGY

Recent advances in artificial intelligence (AI) technologies and robotics are transforming the ways we monitor water and sewer infrastructure, detect changes in water quality and chemistry and optimize pipe distribution networks. This points to a qualitative shift in how data is being generated, stored, disseminated, and translated into useful information that can guide decision making as well as drive core technical and business operations in the water and sanitation sector.

Artificial Intelligence is a key technology in driving the digitalization of water and sanitation utilities. Both AI and machine learning are being increasingly used to offer a wide range of path-breaking applications and solutions to gather data intelligence and optimize operational processes in the water industry. For instance, algorithms and self-learning data-driven models are being used to analyze systems-derived data to detect and anticipate disruptions in piping networks. Machine Learning typically involves building some computer model from data with the ability to make subsequent predictions without the need for additional software programming. Machine learning often goes hand in hand with AI-based applications to offer a wide range of practical and cost-saving solutions. AI-based systems are being used to perform real-time detection of pipe bursts in water distribution networks for instance (International Water Association 2020).

The detection system works by automatically processing pressure and flow sensor signals in near real-time to forecast the signal values in the near future using Artificial Neural Network (ANN) technology[7]. These signals are then compared with incoming observations to collect different forms of evidence about the failure event taking place, which is then processed to estimate the likelihood of the event occurrence and raise corresponding alarms (Romano et al 2014). The system effectively learns from historical pipe bursts and other events to predict future ones.

Elements of the detection system, developed initially as part of a research project, were built into a commercial Event Detection System (EDS). EDS has been in use by a large UK water company since 2015. The system processes data from over 7,000 pressure and flow sensors every 15 minutes. This has enabled the company to detect pipe bursts and related leaks in a timely and reliable manner. In addition to detection, EDS can proactively prevent burst events by

[7] Artificial Neural Network (ANN) is one of the best-known machine learning methods that works by mimicking biological neural networks that exist in the human brain. ANNs learn from training data presented to them in order to capture the functional relationships among the data, even if the underlying relationships are not known or the physical meaning is difficult to explain. This enables the ANNs to discover patterns in data that are often unknown, even to the best experts in the field.

detecting equipment failures that often precede these events (e.g., pressure reducing valve failures). EDS does not rely on simulated data; it works solely by extracting useful information from sensor signals where bursts and other events leave their imprints (i.e., deviations from normal pressure and flows signals). This makes the system robust and scalable as it enables data to be processed in near real-time (i.e., within a 15-minute time window). The use of EDS has resulted in major operational cost savings to date for the company, as well as reduced leakage in its piping distribution network and improved service to over 7 million customers.

Despite the huge benefits with adopting AI-based technology, there is still scope for improvement. Event detection systems have suffered in the past from false alarms, for instance, which can impact service delivery and customer relations. Work is being done to address this issue through the development and application of threshold-based criteria that can significantly increase true detection rates.

In addition to AIs, robotic assistive technologies are being used to build and improve automation processes in the water industry. A lot of these technologies are in the early phases of development and experimentation but are showing promising results. These technologies are expected to get scaled up in the future and could offer huge benefits for the water sector and related industries.

Researchers at the University of Bristol are currently experimenting with 'Pipebots', miniaturized robots deployed to assess and monitor buried water and sewage pipe networks in the UK (Zhang et al. 2022). This innovation builds upon recent advances in sensors, nano- and micro-electronics research, communication and robotic autonomous systems and aims to develop a completely new pervasive robotics sensing technology platform which is fully autonomous. These robots will be able to travel, cooperate and interrogate the pipes from the inside, detect the onset of any defects continuously, navigate to and focus on sub-millimeter scale defects to examine them in detail, communicate and guide any maintenance equipment to repair the infrastructure at an early sign of deterioration. By making use of the propagation of sonic waves and other types of sensing these robots can monitor any changes in the condition of the pipe walls, joints, valves, and lateral connections; they can detect the early development and growth of sub-millimeter scale operational or structural faults and pipe corrosion. This innovation will be the first of its kind to deploy swarms of miniaturized robots in buried pipes together with other emerging in-pipe sensor, navigation, and communication solutions with long-term autonomy.

While in its early stages of development, this technology seems very promising. We could see innovations like these quickly advancing from laboratory trials and protypes to field scales and could be easily adapted to suit different geographical contexts. By offering a precise, data-driven and automated solution to managing large, buried infrastructure networks, this technology can provide huge cost saving benefits for routine in-pipe inspection and rehabilitation works.

ICT SOLUTIONS FOR SUSTAINABLE MANAGEMENT OF WATER AND SANITATION INFRASTRUCTURE

Globally, we are facing unprecedented challenges in ensuring that everyone has access to sustainably managed water and sanitation services (see SDG 6.2). Targeted interventions, based on reliable information generated by and shared through ICTs, are essential to overcoming these infrastructural and operational challenges. Without an integrated, data-driven approach to water and sanitation management, we run the risks of overexploiting and polluting already declining freshwater resources and falling short in bridging the gap in water and sanitation needs by 2030 (which is now less than eight years away).

With regards to water, sanitation, and hygiene (WASH), recent initiatives in regions like sub-Saharan Africa offers some glimpse of hope. According to the UN Economic Commission for Africa, rising urbanization in sub-Saharan Africa is leading to a host of challenges, including inadequate housing and a proliferation of compromised environments resulting from the unavailability of sanitation facilities. According to official figures only 55 percent of households in Kenya have access to safe sources of water and 16 percent to sewerage coverage[8]. The delivery of basic services in urban areas has not kept pace with the increasing demand from a rapidly growing population. In the two major cities of Mombasa and Nairobi, for example, there is a water supply deficit of between 100,000 – 150,000 cubic meters annually. Sixty percent of Nairobi's approximately four million inhabitants live in informal settlements where sewer systems are non-existent, making universal access to safe sanitation a significant challenge. Added to this, an estimated 14% of Kenyans practice open defecation. Open defecation practices have been associated with poverty, which poses significant human health risks especially for already vulnerable groups such as children, the elderly, immunocompromised individuals, and low-income families.

These problems are compounded by low levels of investment which poses a significant challenge for expanding water and sanitation infrastructure. The Kenya Environmental Sanitation and Hygiene Policy 2016-2030 shows that due to the slow growth rate of sanitation coverage at only 0.75 percent, achieving SDG 6 by 2030 is very unlikely without significant increases in infrastructural development. The collection of data is also crucial in shaping policy, decision making and resource mobilization and allocation.

Kenya aims to improve access to water and sanitation services and achieve 100% open defecation free status by 2030 in line with sustainable development goal number 6[9]. This calls for deliberate and concerted efforts to increase intra-governmental collaboration across

[8] See link: https://wasreb.go.ke/downloads/WASREB_IMPACT_Issue10_FINAL.pdf
[9] See link: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-019-6459-0

central and county level governments. Kenya's Ministry of Housing, for example, works closely with the Ministry of Water and Sanitation to deliver an integrated approach to adequate housing. These collaborations are designed to include citizen participation and are premised on a human rights approach to development involving the active participation and engagement of different stakeholders. Including people living in poor urban settlements in decision-making processes is seen as crucial for advancing national action plans and programs aimed at advancing water and sanitation rights. This loops in the work of civil society which acts as a third party, not only to ensure accountability, but to contribute to monitoring progress at the national and county levels to keep the government in check and ensure that public resources are used meaningfully.

To advance progress towards these targets, the Kenyan government has partnered with several non-governmental organizations and civil society groups to improve monitoring of water and sanitation status and infrastructure at the community level through the adoption of online and smartphone applications to provide real time notification to service providers. One such initiative is the Open Defecation Free (ODF) Rural Kenya Campaign, which is a community-led sanitation monitoring project that commenced in May 2011. The project was developed primarily to support offline /online data entry at the lowest administrative unit level and improve reporting along multiple gateways through simple visual elements. This initiative has been supported by a web-based Monitoring & Evaluation (M&E) system which is being maintained by Kenya's Ministry of Health with the support of a contracted third-party agency. The primary purpose of this web-based platform is to monitor Kenya's progress towards open defecation free status and to identify entry points where possible for targeted intervention. The web-based platform has since been enhanced through funding support from UNICEF to make it more flexible and user friendly. This integration of ICT has not only resulted in the real time monitoring of water and sanitation status/infrastructure in underserved communities across Kenya but is allowing customers in urban informal settlements using smart mobile phone apps to alert their service providers when pit-emptying services are required.

It is instructive to note that these initiatives are aligned with and supported by an enabling policy environment. To accelerate the realization of these targets in Kenya, the Ministries of Water, Health, and Devolution, and the Kenya National Commission on Human Rights, have developed a monitoring framework on the rights to water and sanitation specific to Kenya in partnership with civil society organizations like Hakijamii, a national organization that works with marginalized groups in helping them claim their economic, social, and cultural rights including the right to water and sanitation. While the framework largely borrows from the global indicators outlined in the SDGs, it localizes targets and sets its own indicators, ensuring that they fit into the Kenyan context. Essentially, the framework is aimed at ensuring the national and county government work together to enable more efficient data collection and reporting. It is designed to measure policy effectiveness; resource allocation and utilization; and five main components of the rights to water and sanitation including affordability, availability, accessibility, quality, and safety.

Further, the framework addresses inequalities by taking into consideration the diverse needs of people living in poor urban and underserved rural areas with no access to water and sanitation and recognizes the importance of their participation in the monitoring process.

USING ICT TO ENHANCE CLIMATE INFORMATION SERVICES

By integrating weather forecasts in the data architecture, digitalization can also make an important contribution towards transitioning to a more resilient and climate-proof water sector. In the Caribbean, there are a number of examples where climate information is being used to drive digital innovation in the water sector and related industries. This includes ongoing efforts to integrate weather and climate forecasting data to guide water service delivery and resource management.

At the regional level, the Caribbean Climate Outlook Forum (CariCOF) initiative, led by the Caribbean Institute for Meteorology and Hydrology (CIMH), has been instrumental in the development and delivery of effective early warning systems, that can provide real-time seasonal climate forecasts and interpretation across relevant time and spatial scales. A key objective of CariCOF is to develop appropriate climate services, tailored to the Caribbean to support regional efforts around climate change adaptation and disaster risk reduction. Since its initiation in the late 1990s, the regional COF has produced and disseminated a range of climate information products including seasonal climate forecasts, consisting of precipitation outlooks and a suite of technical drought early warning (monitoring and forecasting) tools and products geared towards multi-sectoral decision-support, using primarily the Standardized Precipitation Index (SPI), and more recently adding the Standardized Precipitation and Evapotranspiration Index (SPEI) (see Figure 4 for an example of a typical drought outlook).

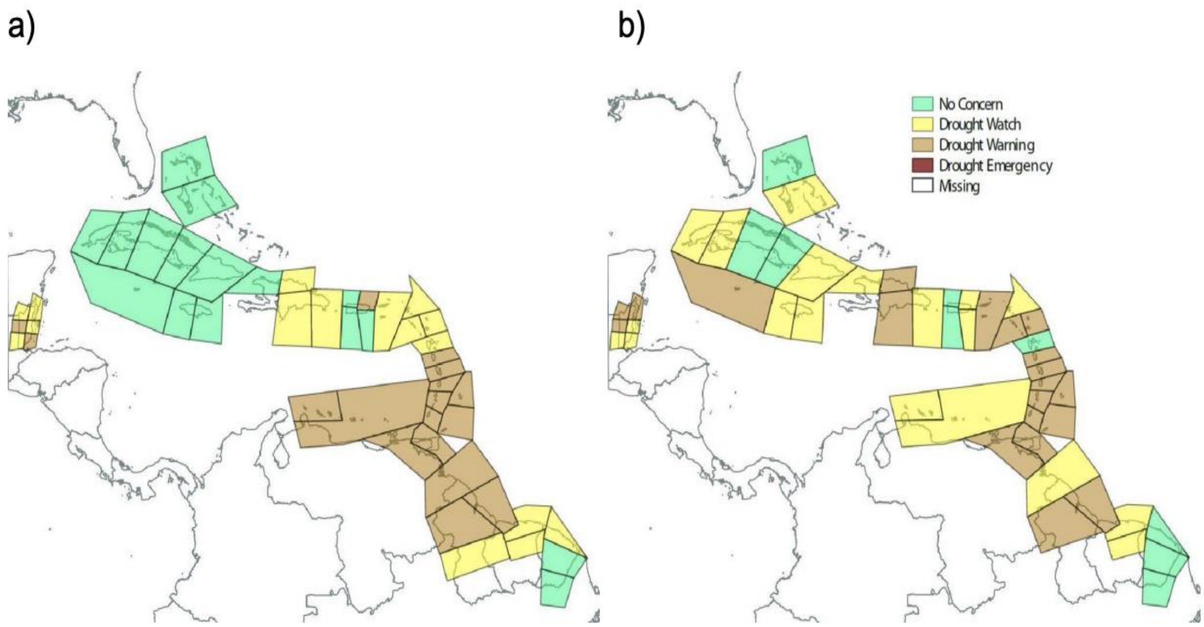

Figure 4: a) Short-term (SPI6) and b) long-term (SPI12) alert levels by the end of May 2020

Source: CIMH

Knowledge sharing and capacity building form a core component of CariCOF. These forums allow for the vital exchange of information between the producers of climate information and end-user communities. Meteorologists learn how decision-makers use seasonal climate information, as well as the challenges to using the forecasts and the impacts of the forecast on different sectors, while decision-makers learn technical aspects of the forecasts and the climate conditions that underpin them. This information can help meteorologists and decision-makers communicate the information to local and national actors more effectively as well as build confidence in the climate products being produced.

Since the 2009-2010 drought event, significant progress has been made in monitoring, forecasting, and mitigating the impacts of drought in the region. Currently, the outlooks are produced through a collaborative effort between some 16 National Meteorological and Hydrological Services (NMHSs) and the CIMH. This collaboration takes place during the training event preceding each CariCOF and are updated electronically every month. Meteorologists use the Climate Predictability Tool (CPT)— a software package that facilitates the generation of the outlooks—to produce a range of objective, probabilistic, national, and regional seasonal outlooks using canonical correlation analysis (Mason and Tippett 2016).

A key innovation with CariCOF is the production of downscaled climate outlooks. This has allowed for targeted intervention to address poor-performing regions and seasons as well as the tailoring of climate information through active engagement with stakeholders and end-user communities. The Caribbean is also transitioning towards a new phase of impacts-based research and product development that extends beyond meteorological forecasting limited to drought hazards, to include a range of other tailored climate products. The Caribbean Climate Impacts Database (CID), an open-source geospatial inventory that archives sector-based impacts from various climate phenomena, is generating new opportunities for advancing climate impact research tailored to specific sectors. This research is foundational to the Caribbean's thrust towards the provision and mainstreaming of sector-specific impacts-based forecasting information for drought and other related hazards like wildfire.

The Caribbean Climate Outlook Forums thus represents a major opportunity for integrating ICT in the regional water sector. The adoption of ICT-based applications can take us one step further in enhancing the ways in which these innovations in climate services can provide effective and sustained solutions to a variety of new and emerging challenges in the water industry. The challenge now is to explore opportunities through ICT adoption to translate the information provided by these climate early warning tools into digital applications within the water sector. Thus, linking data generation with transmission, collation, and analysis through digital innovations at the national level. In other words, the integration of ICT solutions means going beyond just generating data (like the climate outlooks), by using digital technology (including smartphone applications, cloud data infrastructure and other advanced and real-time communication technologies) to drive innovations in areas such as water delivery and resource management. See Figure 5 for an illustration of how ICT could be integrated to enhance the delivery of climate information services in water dependent sectors.

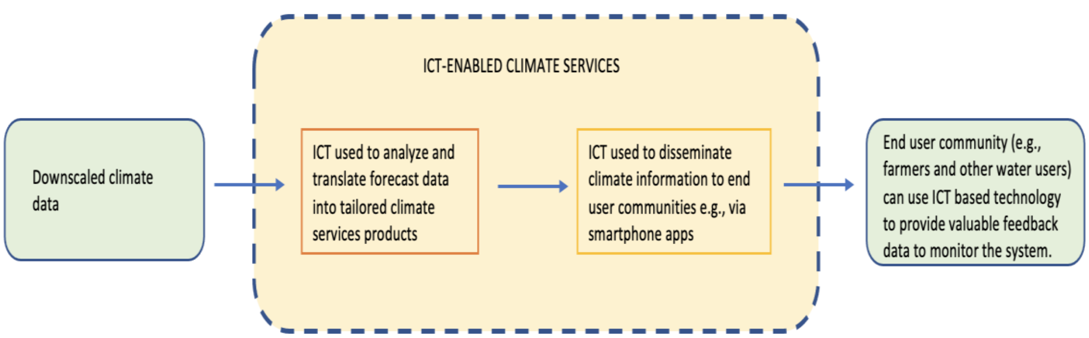

Figure 5: Illustration of how ICT can be used to enhance climate information services

Figure 6: Farmer hand watering melons in field plot in Flagaman St. Elizabeth during 2014 Drought

Source: Photograph taken by Norman Grindley, Jamaica Gleaner

The 2014-2016 drought event – arguably the most severe and widespread drought in the region's history – highlighted the urgent need to enhance investment in ICT and drought risk management at the regional, national, and sectoral scales. Jamaica offers a good example in how the integration of ICTs and climate early warning systems can offer effective solutions in supporting climate-informed decision making at the national level. Beginning in 2014, the Technical Centre for Agricultural and Rural Cooperation (CTA) partnered with the Rural Agricultural Development Authority (RADA) and the Jamaica Meteorological Service (JMS) to train farmers in adopting climate-smart agricultural practices. The JMS trained small farmers in the parishes of St Mary, Portland, and St Thomas to use weather advisory services using smart phones to prepare for droughts and possible floods. The information for the advisories was generated from the JMS drought monitoring tool that provides SPI forecast on a quarterly timescale[10]. In 2014- 2015, Jamaica experienced one of the worst droughts in its history, with a 30% decline in agricultural production island-wide. A follow-up assessment of 600 farmers after the drought had ended found that the farmers who had no information lost about 72 percent of their production on average compared to farmers who had access to this information who lost only 39 percent.

[10] See link for Jamaica Meteoroligal Service website: http://metservice.gov.jm/climate-products

Achieving useful skill – as demonstrated by the 2014-2015 case – is possible, at least in part, thanks to the larger interannual variability of 3-monthly rainfall totals in Jamaica as compared to the eastern Caribbean, for instance[11]. The JMS is also set to release its bushfire forecast tool, as it continues to build on its collaboration with the Jamaica Fire Brigade.

ACHIEVING DIGITAL TRANSFORMATION THROUGH SMART WATER INFRASTRUCTURE TECHNOLOGIES

The integration of digital tools in the water and sanitation sector can address real challenges and provide tangible benefits to the sector, including supporting areas such as real-time monitoring, predictive maintenance, process control, and forecasting. At the national scale, a number of water utilities have been utilizing smart water infrastructure technologies (SWIT) such as smart metering, remote water quality monitoring and remote leakage detection to improve efficiency across the sector. SWIT have the potential to significantly enhance water service delivery and efficiency, reduce costs and water losses, streamlining operation and maintenance, improving data and asset management in water utilities, improving customer service and satisfaction, and allowing for information-based decision making.

The implementation of integrated Management Information Systems, for example, can help streamline activities such as billing, customer relations, asset inventory and management, and customer metering, that allow for greater efficiency in the day-to-day operations of water utilities. The adoption of MIS has aided many water utilities in improving the monitoring of unbilled or under-billed usage and non-revenue water. Similarly, smart metering is a component of the smart grid that allows a utility to obtain meter readings on demand (daily, hourly or more frequently) without the need of manual meter readers to transmit information. There are two types: (1) automated meter reading (AMR), and (2) automated metering infrastructure (AMI). Automated Meter Reading (AMR) includes the walk-by and drive-by methods as well as a fixed network, usually with only one-way communication from the meter to the billing system. Automated Metering Infrastructure (AMI) refers to a fixed network system, with smart meters providing two-way communications between the water meter and the utility. Using smart metering technology allows water utilities to improve their efficiency through more accurate and time saving collection of customer meter data and by eliminating the costs of routine meter reading. Smart meter systems also allow for the quick identification of failed and failing meters before actual billing, improving the utility's cash flow (Arniella, 2017). See Table 2 for an outline of key advantages and disadvantages associated with smart metering.

[11] See link for Caribbean Regional Climate Center website: http://rcc.cimh.edu.bb/caribbeanclimatology

Table 2: Advantages and Disadvantages associated with Smart Metering Technology

Pros and Cons with Smart Meters	
Advantages	**Disadvantages**
Lowering the cost of meter reading by eliminating manual meter reading	Front-end capital investment
Reducing billing errors and disputes	Long-term financial commitment to the new metering technology and related software
Monitoring the water system in a timely manner	Ensuring the security of metering data and preventing cyber-attacks
Providing useful data for balancing customer demand	Transitioning to new technology and processes require proper training
Enabling possible dynamic pricing (raising or lowering the cost of water based on demand, promotions, and customer incentives)	Managing public reaction and customer acceptance of the new meters
Assessing Non-Revenue Water in real time or short intervals	Managing and storing vast quantities of metering data and
Providing real-time billing information, reducing estimated readings and re-billing costs	Replacing and disposing of the old meters
Improving the monitoring of potential meter tampering and water theft	
Detecting water line leaks sooner, so they can be repaired faster	

Source: Adapted from Arniella (2017) Evaluation of Smart Water Technologies

SWITs are being implemented in several countries in the Caribbean, however there is limited information available as to how well these technologies are being integrated in the daily operational activities of water utilities. Based on the information available, it would suggest that progress is being made, particularly in terms of automated meter reading and data management. Since 2011, the Barbados Water Authority (BWA) has implemented several SWIT related initiatives, including hydraulic metering, an integrated management information system, smart metering and a supervisory control and data acquisition (SCADA) system. The BWA is the entity responsible for supplying the entire island of Barbados with potable water as well as provide wastewater treatment and disposal services to the sewered areas of Bridgetown and the island's South Coast. The Authority is also responsible for the monitoring, assessment, control, and protection of the country's water resources. Prior to 2011, the BWA's operations were being hampered by a poorly integrated network, that prevented accurate and routine monitoring of the island's water infrastructure. Through funding from the Inter-American Development Bank (IDB), the BWA was able to develop a long-term strategic and action plan to improve its economic efficiency, service quality, financial and institutional sustainability and strengthening its water infrastructure.

Over the last decade the BWA has embarked on several projects as part of its wider goal of building a smart water grid. This includes the implementation of an integrated management information system. This includes improved customer information systems (CIS), work order management, and commercial – billing systems. The MIS is expected to handle data from 50,000 customer meters. It will also include 200 commercial customers on AMR drive-by networking system.

The BWA has also georeferenced all of its customer meters, which forms part of the Authority's broader effort to develop and establish a District Metered Areas (DMAs) as a critical step towards its Non-Revenue Water (NRW) reduction strategy by end of 2023[12]. This project is dependent on the calibration and functionality of the hydraulic model and is crucial for the full implementation of the AMR meter replacement. The BWA also recently established a new NRW Department is responsible for coordinating these activities. The project will involve the installation of automated electromagnetic metering points in the distribution system that will help determine the losses in defined geographic areas and aid in setting a baseline by quantifying the water losses for each DMA.

The BWA has also developed a Supervisory Control and Data Acquisition (SCADA) system that allows for the real time monitoring of reservoir levels and the remote detection of faults at pumping stations, including power outages or leakages, if they occur. The SCADA system also allows for improvements in communication with field staff which improves response time in the field and enhance the day-to-day operations of the BWA. Additionally, the information gathered can help form a useful baseline for monitoring the system overtime.

The case of BWA seems like a good example of ICT adoption at the national level. Findings from the desk study suggest that these various ICT technologies are being implemented alongside capacity building and institutional strengthening. There is limited data however, to verify how these activities are playing out on the ground and the extent to which the data is being used to transform service delivery. The BWA has since trained several of its personnel in procuring and implementing SWIT. However, there is still room for improvement and further skills training especially as the Authority seeks to transition fully towards a smart water grid, to take full advantage of these new technologies.

[12] This project has benefited from funding support from the Caribbean Development Bank (CDB) and the European Union.

CONCLUSION AND KEY MESSAGES

This position paper explores opportunities and challenges for integrating ICTs in the regional water sector. The paper is informed by a desk review of regional and international examples of ICT adoption and mainstreaming in the water and sanitation sector. International case studies are drawn to demonstrate examples where ICTs are being adopted and applied within both developed and developing region context. Mindful of course that the contexts may differ substantially between and even within regions, these case studies are only meant to serve as illustrative examples of ICT adoption and integration rather than drawing direct comparison with the Caribbean.

As aforementioned, we are facing unprecedented global challenges in ensuring that everyone has access to sustainably managed water and sanitation services. Shifting population patterns and rapid urbanization, persistent poverty, unsustainable land use and market transitions and unprecedented changes in the global climate system are all impacting our ability to manage water resources globally. These will have a range of multiplier and knock-on effects with dire implications for human health and well-being. Changes in water availability and quality will impact food security and health, which have proven to be triggers of political instability and civil strife around the world.

Overall, the water and sanitation sector need to be prioritized if we are to transition to a safer and more sustainable world. Water resources are becoming more and more scarce and the costs of upgrading sanitation and supplying water (for drinking as well as all other human activities) are rising. Also, these unprecedented changes in both human and ecological systems are making the technical, political, and financial challenges of service delivery even more complex, especially under a rapidly warming world. The complex and dynamic nature of these challenges requires smarter approaches to water resource management that can improve the sustainability and scalability of water and sanitation services. The SDG 6 goal commits us to ensuring the availability and sustainable management of water and sanitation for all by 2030. Technology will play a pivotal role in achieving this ambitious goal, not just in terms of engineering technology in the delivery and maintenance of water and sanitation facilities and systems (such as taps, toilets and pipework), but also in the more extensive use of ICTs in helping us to manage water itself – the resource on which sanitation and hygiene depend.

These realities have significant implications for the Caribbean. The adoption and integration of ICT in the regional water sector will generate a wide range of benefits. That said, as illustrated in this position paper, it is important to note that the Caribbean is not starting from scratch. In fact, there are several examples of successful ICT integration underway among regional water utilities. There is however room for improvement and greater adoption and mainstreaming of

ICTs throughout the entire water sector. The level of ICT adoption and integration is also quite uneven between different countries in the region.

The desk study offers several important lessons and insights regarding the benefits and shortcomings of ICT adoption in the water and sanitation sector. Key **advantages** include:

- Reducing the duration and costs of monitoring and inventory activities. Accurate data and information management systems are a precursor for sound management, monitoring and evaluation, and decision support systems. ICTs can help make data transfer more efficient, reduce manual data errors, and increase the frequency of monitoring due to relative cost effectiveness.
- Advanced monitoring also allows for better planning and management, especially during cycles of drought and flooding.
- Improves efficiency gains of water service providers. ICTs can enable shortened response time, reduce travel distance and maintenance costs, optimize operations (production costs, energy efficiency etc.) and improve quality of service. ICTs through the application of smart technologies are also proving effective in the treatment and recycling of wastewater.
- Improves collection rates of water service providers through ICT based-payment systems. Some of the most common ICTs adopted by utilities are e-payment systems which offer payment facilitation and increased reliability in billing and payment recovery, reduced administrative and payment transaction costs, and improved revenue collection.
- Ensure better services to the poor. The use of mobile phones, for instance, can serve the development needs of the poorest and most vulnerable populations. They represent a widespread and relatively low-cost communication option for rapid information transfer and service facilitation whilst eliminating prevalent issues of distance and time.
- Strengthen community participation and accountability frameworks. ICTs can be used to empower communities, promote public participation, encourage citizen science, and create a system of transparency and accountability.
- Could aid in eliminating wastage and other forms of non-revenue water (NRW) losses. ICTs can help monitor NRW in real time or over short intervals. The adoption and implementation of customer information systems can also aid in reducing billing errors and disputes by providing real-time billing information, reducing estimated readings and re-billing costs.
- Could potentially reduce risk/vulnerability to climate and non-climate hazards (e.g., droughts, poor water quality and spread of diseases) due to improvements in the collection, collation, monitoring and dissemination of data.
- Scalability; ICT solutions can be applied at a variety of scales, from national and regional levels to site-specific interventions.

Possible **shortcomings and considerations** include:

- High front-end capital investment usually required. Governments and utilities have been able to address this through fostering strategic partnerships with international development organizations, the private sector, and other non-governmental groups.
- Transitioning to new technologies and e-governance systems require proper training and retooling of human capital. Also need to engage with the public to improve awareness and acceptance of these changes.
- Strengthening of institutional capacity to collect, store, secure, and manage vast quantities of data. This also points to the need to foster an enabling environment that foster cooperation and knowledge sharing.
- Large-scale adoption of ICT will pose several cyber security risks and concerns. The digitization of data and the expanding use of high-speed internet have increased the risk of hacking and other forms of sabotage that may disrupt the proper functioning of critical ICT-powered infrastructure and software. Significant investments will be necessary to counter these threats and preserve the integrity of ICT systems.
- Data governance needs to be a key consideration to ensure transparency and accountability and safeguard data reliability, quality, and access.

In terms of **key messages**, there are several considerations to keep in mind. Firstly, good governance remains a key and necessary pre-requisite for ensuring the successful mainstreaming of ICT in the water and sanitation sector. Good governance and information driven decision making, based on reliable information gathered by and shared through ICTs, are essential to manage uncertainty and reduce the risks of overexploitation and pollution of water resources and to extend and maintain effective and efficient sanitation systems that are proven to massively reduce the spread of disease. Without an integrated, data-driven approach to water and sanitation that takes account of the multiple and intersecting needs of different stakeholders, and the need to protect vital ecosystem services, we risk jeopardizing the success of the SDGs as a whole. In general, strong, and decisive leadership and commitment and fostering an enabling policy environment are key to the successful integration of ICT in the water and sanitation sector.

There is also no one-size-fits-all solution to integrating ICT in water and sanitation services. Efforts need to be grounded in the local realities and contexts that give rise to the challenges in which they seek to address. This calls for the adoption of practical and culturally acceptable technologies that can aid in developing innovative, efficient, scalable solutions, based on data-driven evidence. We need to adapt the technologies that are already available, mixing physical infrastructure, data management and communication in different ways to meet the needs of different contexts and differently positioned social groups and actors. Bearing in mind that the integration of ICT is an evolving journey. It requires changes to existing institutional culture coupled with the integration of digital tools that supports the progress of the water sector along the digital maturity curve, from the opportunistic deployment of digital solutions to a more transformative one.

And lastly, we need to be attentive to scale. While projects at the regional and national levels are extremely important, we must also focus on solutions that are suited at the community or household level as well. The inclusion, buy-in and active participation of communities are important if we are to transition successfully towards an ICT-enhanced landscape. Households and other beneficiary communities must play a key role in monitoring and conservation efforts as well. ICTs can help do that, for instance through the use of smart water technologies and infrastructure like meters and apps to monitor home usage or through enabling citizen action where people living in underserved informal urban settlements or rural farmers, can use mobile phones to collect and share information on the level and status of water and sanitation infrastructure. Engaging key stakeholders like youth and the research community, could offer immense opportunities for innovation. The winner of the inaugural GWP-C Young Caribbean Water Entrepreneurs Shark Tank Competition, Yekini Wallen-Bryan, showcased the development of a line of devices centered around remote monitoring, control and automation of the assets and environments of homeowners, business places and other public and private entities. This includes the PowerPree – a device and app/website that gives customers the ability to monitor and control their electrical appliances from anywhere in the world from their smartphone or computer as well as monitor their energy usage in real time. Yekini's pitch focused on the water equivalent (WaterPree), which is in the development stage, and will allow people to monitor and control their water usage from their smart phones. The system is the first internet-of-things solution for utilities that has been developed and manufactured in the Caribbean region. It also offers an innovative platform that can facilitate real-time data analytics, reporting and forecasting for the water sector in Yekini's home country, Jamaica, and the wider Caribbean region.

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