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Science
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Ensuring Safe Water and Sanitation for All

A Solution through Science, Technology and Innovation

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Note

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This series of publications seeks to contribute to exploring current issues in science, technology, and innovation, with particular emphasis on their impact on developing countries.

The term “country” as used in this study also refers, as appropriate, to territories or areas. In addition, the designations of country groups are intended solely for statistical or analytical convenience and do not necessarily express a judgment about the stage of development reached by a particular country or area.

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Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AI	Artificial Intelligence
AP-PLAT	Asia Pacific Climate Adaptation Information Platform
ATMs	Automatic Teller Machines
BMGF	Bill and Melinda Gates Foundation
CAF	Development Bank of Latin America
CBFEWS	Community Based Flood Early Warning System
CSTD	Commission on Science and Technology for Development
CWDF	China Women's Development Foundation
EUWI+	EU Water Initiative Plus
FAO	Food and Agriculture Organization
FSM	Fecal Sludge Management
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWP	Global Water Partnerships
GWSP	Global Water Security & Sanitation Partnership
IMTA	Mexican Institute of Water Technology
INAPA	Dominican Republic National Institute of Potable Water and Sewage
IoT	Internet of Things
ISTP	Independent Sewage Treatment Plant
ITU	International Telecommunications Union
IWRM	Integrated Water Resources Management
LDCs	Least Developed Countries
LLDCs	Landlocked Developing Countries
NGO	Non-Governmental Organization
NOWPAP	Northwest Pacific Action Plan
NPEC	Northwest Pacific Region Environmental Cooperation Centre
OECD	Organization for Economic Co-operation and Development
OHCHR	Office of the United Nations High Commissioner for Human Rights
OLAS	Latin American and Caribbean Water and Sanitation Observatory (OLAS)
POUs	Point of Use Systems
R&D	Research and Development

RDI	Research, Development and Innovation
RVO	Netherlands Enterprise Agency
SCUWO	Schemes of Comprehensive Use and Protection of Water Objects
SDC	Swiss Agency for Development and Cooperation
SDGs	Sustainable Development Goals
SDPI	Sustainable Development Performance Indicator
SFW	Swiss Fresh Water
SHOFCO	Shining Hope for Communities
SIASAR	Rural Water and Sanitation Information System
SIDS	Small Island Developing States
SSA	Sub-Saharan Africa
STI	Science, Technology, and Innovation
SUWASA	Sustainable Water and Sanitation in Africa
SWA	Sanitation and Water for All
TIP	Transformative Innovation Policy
TIS	Technological and Innovative Solutions
UN DESA	UN Department of Economic and Social Affairs
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNICEF	United Nations International Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
UNRISD	United Nations Research Institute for Sustainable Development
UNWTO	United Nations World Tourism Organization
USAID	United States Agency for International Development
WAH	Water Action Hub
WASH	Water, Sanitation and Hygiene
WfWP	Women for Water Partnership
WHO	World Health Organization
WHOS	World Meteorological Organization Hydrological Observing System
WMO	World Meteorological Organization
WSIS	World Summit on the Information Society
WWC	World Water Council

1. Introduction

Access to safe water and adequate sanitation is a basic human right. While progress has been made towards the achievement of the Sustainable Development Goal on water and sanitation (SDG 6), the trends and current status of access to water and sanitation provide cause for concern. There is an urgent need to devise solutions that accelerate progress and ensure that no one is left behind. Nearly every other Sustainable Development Goal relies in some way on the achievement of SDG 6. Together with good hygiene practices, for instance, it is essential for the achievement of good health and well-being (SDG 3) and gender equality (SDG 5) as well eliminating poverty (SDG 1) and reducing inequalities (SDG 10). As a determinant of success in areas including agriculture, energy, and disaster resilience, it has vast and consistently underestimated socio-economic impacts.

Whilst factors including better policies and governance, increased funding, improved infrastructure, and increased data availability for better decision-making are central to resolving water and sanitation issues, there is no doubt that Science, Technology, and Innovation (STI) can play a particularly significant role. Responses to the COVID-19 pandemic demonstrated the vital role of STI in delivering solutions to critical challenges. Countries are now more attentive to the development and deployment of new technologies and processes. New applications of existing technology and techniques have great potential to increase the efficiency of existing water and sanitation systems and to secure water and sanitation for all. STI for water has thus played a central role in discussion at recent international water policy events.[1] It will be a key focus in the upcoming 2023 UN Water Conference and the 2022 International Water Association Congress in Copenhagen.

This paper explores the role of STI as key enablers of catalytic actions toward achieving universal access to safe water and sanitation. The second chapter will discuss the progress in implementing SDG 6 and challenges in meeting its targets. The third chapter will provide an analytical framework for and examples of practical STI solutions which address issues in providing water and sanitation services. Chapter four highlights the global effort to build partnerships and cooperation in achieving SDG 6. Finally, chapter five will propose recommendations to be considered by policymakers and the international community.

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[1] These include the Stockholm International Water Institute (SIWI) World Water Week in August 2022, the Singapore International Water week in April 2022 and the World Water Forum of the World Water Council, held in March 2022.

2. Persistent challenges of ensuring water and sanitation for all

SDG 6 calls for ensuring universal access to safe and affordable drinking water and sanitation, the provision of hygiene, and the ending of open defecation. Important within this goal is the recognition that sustainably managing water goes far beyond simply providing safe water supply and sanitation services. It requires addressing the broader water context, including improving water quality and wastewater management, increasing water use efficiency in order to use freshwater resources sustainably and reduce water stress,[2] implementing integrated water resource management, and protecting and restoring water-related ecosystems. To this end, it has set multiple targets.

2.1 Global Progress in implementing SDG 6

A review of the global status of progress towards meeting the multiple targets indicates that the world as a whole is not on track to achieve SDG 6 (See Table 1) and many countries are even going backwards (UN-Water, 2021).

While progress is slow against all sub-goals and targets, there are two areas of particular concern: universal access to safely managed drinking water services and safely managed sanitation services, and the implementation of integrated water resource management.

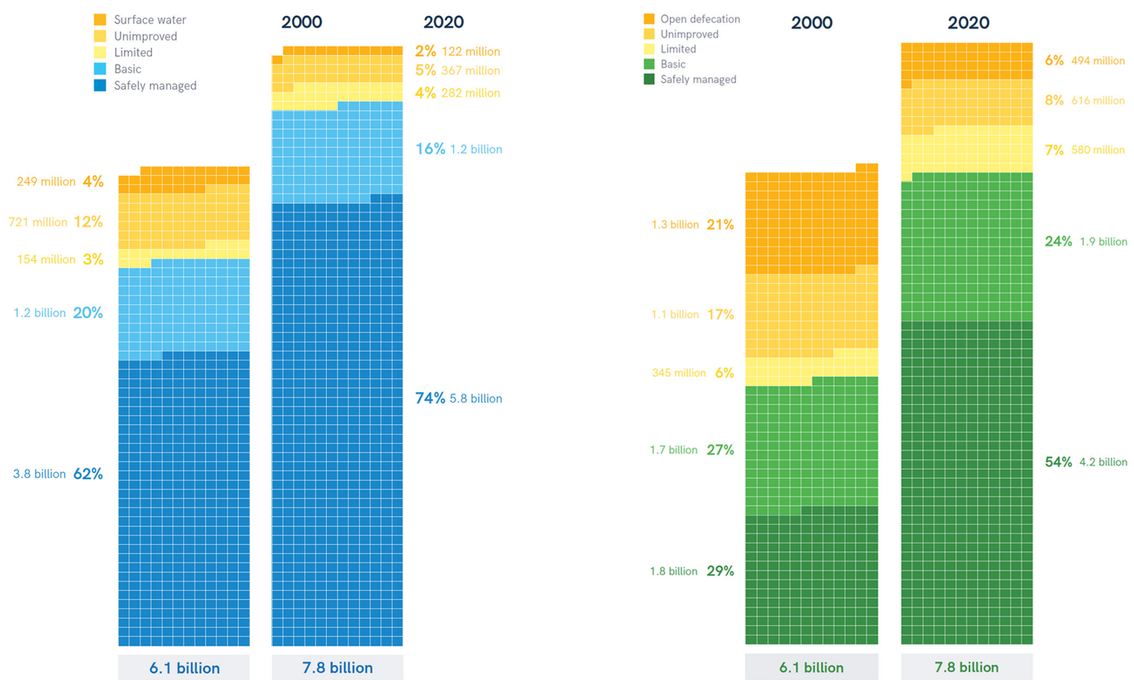
While the number of people lacking safely managed services has decreased by significantly in recent years, 2 billion people still lacked access to safely managed drinking water services in 2020 (UN-Water, 2021). Of this, 1.2 billion people could not obtain even basic services, 282 million did not have services when needed, 367 million relied on sources that do not protect against contamination, and 122 million were drinking surface water directly (WHO and UNICEF, 2021).

Limited progress has been achieved in enhancing access to sanitation, with only 2.4 billion people having access to safely managed sanitation services in 2020. Only eight countries, all of them high-income, had reached universal coverage to safely managed sanitation services. Of the 1.9 billion people who lacked access to even basic sanitation services, 494 million still practice open defecation (WHO and UNICEF, 2021).

If current trends persist, only 81% and 67% of the world's population will have access to safely managed water and sanitation services, respectively, by 2030 (WHO and UNICEF, 2021). This means that 1.6 billion people and 2.8 billion people will be left behind, without safely managed water and sanitation services, respectively. Achieving these targets by 2030 will require a fourfold increase in the current rate of progress (UN-Water, 2021).

[2] Water stress occurs when water demand exceeds available water resources at a specific place and time.

Figure 1
Trends in access to water and sanitation services, 2000-2020 (% of global population)



Source: WHO and UNICEF, 2021

Box 1
Perspectives of national water leaders on achieving SDG 6.

A recent survey of national water leaders, i.e., those with water leadership responsibility, from 88 countries that are home to over 6 billion people. The survey mapped key issues faced by these countries in improving water outcomes. It was found that only two of the SDG 6 water targets surveyed are considered either 'achieved' or 'not difficult to achieve' by national water leaders of more than half of the surveyed countries. These two targets pertain to transboundary cooperation and participation. The remaining six SDG 6 targets are all considered to be either 'challenging' or 'impossible' to achieve for the majority of surveyed countries. Moreover, the proportion of surveyed countries for which achieving an SDG target is considered 'challenging' or 'impossible' is broadly similar for upper-middle, lower-middle-, and low-income countries. The survey also indicated that while governance related challenges pose the biggest barrier to achieving targets relating to the protection of ecosystems, integrated water resource management, local participation and transboundary cooperation, the lack of financing restrains progress on the targets relating to drinking water, water use efficiency, water quality, and water scarcity.

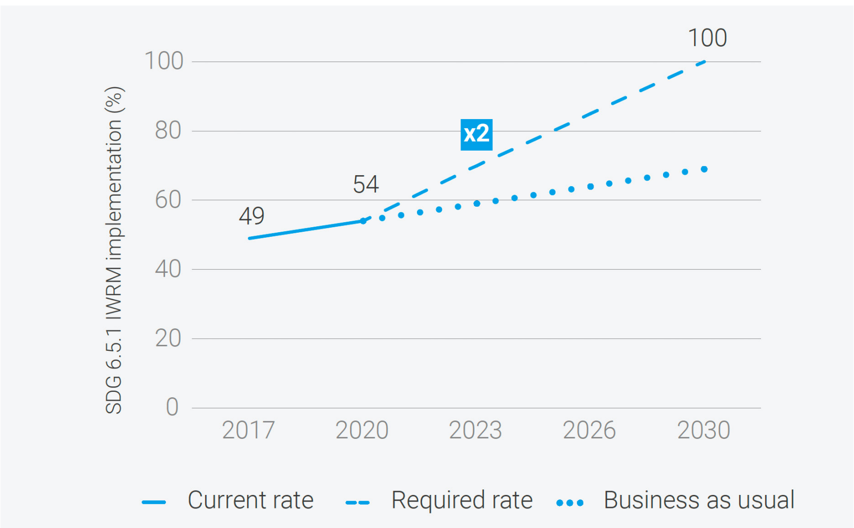
Source: Water Policy Group, 2021

The second area of particular concern is the implementation of integrated water resource management (IWRM). IWRM promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. It allows for multiple benefits to stem from a single intervention and is essential to securing a sustainable and resilient water and sanitation future.

IWRM is measured by 4 main components: 'Enabling environment', 'Institutions', 'Management instruments' and 'Financing'. The key features of IWRM include managing water resources at the lowest possible level; optimizing supply; managing demand; providing equitable access to water resources through participatory and transparent governance and management; establishing improved and integrated policy; regulatory and institutional frameworks; and utilizing an inter-sectoral approach to decision making (Global Water Partnership, 2018).

107 countries are not on track to meet this target (UNEP, 2021). The global call for IWRM implementation is not new: it was formalized in 1992 during the International Conference on Water and the Environment in Dublin, Ireland. Despite this, 30 years later, 87 countries continue to report "low" or "medium-low" levels of IWRM implementation (UNEP, 2021). In the absence of coordinated policy, legislative and regulatory frameworks, financing, transparent management of data and information, and multi-stakeholder planning across all sectors and at all levels, it is difficult to balance competing water demands from across society and the economy to achieve SDG6. To achieve our aims, the rate of IWRM implementation must double (UN-Water, 2021).

Figure 2
Current and required global IWRM implementation rate



Source: UNEP, 2021

Table 1
SDG 6 Targets and Indicators

Sub-Goals	Objectives	Indicators	Global progress status
6.1	Universal and equitable access to safe and affordable drinking water.	Proportion of population using safely managed drinking water services.	74% of the world's population used a safely managed drinking water service in 2020
6.2	Adequate and equitable sanitation and hygiene for all and end to open defecation.	Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water.	54% of the world's population used a safely managed sanitation service in 2020 71% of the world's population had a handwashing facility with soap and water available at home in 2020
6.3	Improvement of water quality through reduction of water pollution.	Proportion of wastewater safely treated; Proportion of bodies of water with good ambient water quality.	56% of the world's domestic wastewater was safely treated in 2020 72% of the world's monitored water bodies had good ambient water quality in 2020
6.4	Increase of water use efficiency across sectors and reduce number of people suffering from water scarcity.	Change in water-use efficiency over time; Level of water stress: freshwater withdrawal as a proportion of available freshwater resources.	Water use efficiency has increased by 10% globally between 2015 and 2021 2.3 billion people lived in water-stressed countries in 2021 19% of the world's renewable water resources were being withdrawn after taking into account environmental flows requirements in 2019
6.5	Implementation of integrated water resource management at all levels.	Degree of integrated water resources management implementation (0-100) Proportion of transboundary basin area with an operational arrangement for water cooperation.	107 countries are not on track to have sustainably managed water resources by 2030 58% of the world's transboundary basin area had an operational arrangement for water cooperation in 2020.
6.6	Protect and restore the health of water-related ecosystems.	Change in the extent of water-related ecosystems over time.	A fifth of the world's water basins were experiencing rapid changes in the area covered by surface waters in 2020, indicative of flooding and drought events associated with climate change.
6.a	International cooperation and capacity building in developing countries through wastewater treatment, desalination, recycling, and reuse technologies etc.	Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan.	Water- and sanitation-related official development assistance increased by 9% between 2015-2019 stood at stood at USD 8.7 billion in 2020, but there was little change in disbursements
6.b	Participation of local communities for improvement of water and sanitation.	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management.	Only 14 countries reported having high levels of Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management.

Source: UN-Water, 2015, 2021
Note: not all countries report data on all indicators

2.2 Inequality in access to water and sanitation

The trends in access to water and sanitation noted above hide important inequalities and inequities in access to water and sanitation that manifest themselves at different levels.

The first level of disparity is between regions, with Sub-Saharan Africa (SSA) falling furthest behind. Coverage of safely managed drinking water services stood at 96% in Europe and Northern America in contrast to 30% in SSA. Similarly, 78% of the population in Australia and New Zealand had access to safely managed sanitation services in contrast to 34% in Latin America and the Caribbean, and 21% in SSA (WHO and UNICEF, 2021). In fact, the number of people lacking basic sanitation services in SSA increased between 2000 and 2020, as the population grew by 73% over the same time period, although 290 million gained access to at least basic sanitation services during this time (WHO and UNICEF, 2022).

Nearly half of those without access to basic drinking water services in 2020 lived in the Least Developed Countries (LDCs). The disparity can also be seen in the quality of facilities and services across regions. Almost the entire population in Europe and North America has generally contaminant-free water available on premises and on demand. Conversely, only 36% of the population in Oceania had access to water when needed, while only 36% of Sub-Saharan Africa had access to contaminant-free water (WHO and UNICEF, 2021). Countries characterized as LDCs, Small Island Developing States, or Landlocked Developing Countries and countries in Sub-Saharan Africa and Central and Southern Asia have a greater share of population using on-site sanitation facilities.

For LDCs, where the highest priority is to simultaneously close the large gaps in access to water and energy, ensure food security, and promote growth in other economic sectors, the nexus of water and other systems could lead to constraints in ensuring water for all when needed. Low-carbon energy sources can support both energy and water security goals (through a reduction in water demand and wastewater) as long as the low-carbon alternative represents a less water intensive alternative to higher carbon fuels (Kerres et al., 2020). It is worth noting that some future energy options which may be key to several countries' goals under the Paris Agreement, including carbon capture and storage and biofuels, could worsen water stress in regions already experiencing water scarcity (Rosa et al., 2020). Increased demand for water may have to be met using seawater and other non-traditional sources such as treated wastewater. The processes necessary to make these waters usable in turn likely require more energy.

Second, coverage varies widely within regions. In Eastern and South-Eastern Asia, for instance, coverage of safely managed drinking water services stood at 99% in Malaysia compared with 18% and 28% in Lao People's Democratic Republic and Cambodia, respectively. While North American countries and some in South America, notably Chile, enjoy close to universal access to clean water, many countries in Latin America such as Ecuador and Mexico still have large proportions of households without access to adequate hygiene and sanitation solutions or accessible drinking water, cannot dispose of their excrement adequately, or do not have handwashing facilities (WHO and UNICEF, 2021).[3] Similarly, in sub-Saharan Africa, national coverage of safely managed drinking water services ranged from 94% in Réunion[4] to a mere 6% in Chad. Globally, nearly half of those without access to basic drinking water services in 2020 lived in the least developed countries. On the sanitation side, in North Africa and Western Asia, Kuwait exhibited 100% coverage in comparison to Lebanon, Algeria and Yemen where coverage ranged between 16% and 19% (WHO and UNICEF, 2021).

Significant disparities are also observed within countries, primarily due to important differences between urban and rural coverage, with rural populations having significantly lower levels of access

[3] Contribution from the Government of Ecuador.

[4] Réunion is a French overseas territory

to safe water and improved sanitation as compared to their urban counterparts. Globally in 2020, 86% of the urban population had access to safely managed water services, compared to only 60% of rural inhabitants (WHO and UNICEF, 2021). However, recent trends of rapid and unplanned urbanization have resulted in the number of urban residents without access to safely managed drinking water nearly doubling since 2000. Despite this, those who lacked access to basic water services, the overwhelming majority (8 out of 10) lived in rural areas (UN-Water, 2021).

Rural access to safely managed sanitation services (44% of the population) also lagged behind urban areas (62% of the population). Urban areas also experience a better quality of services, with two thirds of the covered urban population having sewer connections compared to one in seven people in rural areas, where on-site sanitation facilities are more common (WHO and UNICEF, 2021). For example, Romania is among the lowest ranking countries in European Union regarding the rate of connection of the population to water services (72.4%), and for sewerage services (57.4%). The differences between urban and rural areas in Romania are huge, with smaller communities in rural areas lagging considerably.[5]

The fourth level of inequality relates to people belonging to vulnerable, marginalized, and disadvantaged groups, in particular women and the disabled who face additional barriers to accessibility, availability and quality of services (Van de Lande, 2015). Persons with disabilities, especially those living in developing countries, are disproportionately affected by challenges to access water and sanitation: although data is scarce, evidence from a small set of developing countries indicates that more than one in seven persons with disabilities finds the toilet at home hindering or not accessible. For instance, most public toilets in developing countries are inaccessible to wheelchair users, although the figure remains low even in developed countries with only 69% of public toilets being accessible to wheelchair users (UNDESA, 2020). A survey of 20,000 households in Bangladesh found that 79% of people with disabilities were unable to collect water while 47% of people with disabilities were unable to access sanitation facilities without coming into contact with fecal matter (Scherer et al., 2021).

Women and girls experience discrimination and inequalities in access to water and sanitation in various ways. In developing countries, socially and culturally induced gender responsibilities result in water management activities being assigned to women and girls. Studies indicate that in some countries such as Mauritania, Somalia, Tunisia and Yemen, a single trip takes longer than an hour. A 2016 study of 24 sub-Saharan countries estimated that 3.36 million children and 13.54 million adult women were responsible for water collection (UNICEF, 2016). Limited access to water and sanitation facilities and services leads to a deterioration of physical and psychological health outcomes. Fetching water from long distances or using water and sanitation facilities that are not on premises also exposes women and girls to a greater risk of physical and sexual violence (Scherer et al., 2021; Assefa et al., 2021). With one in three schools globally lacking access to basic water and sanitation (WaterAid, 2017), girls in particular stand to lose out on access to education.

2.3 Increasing challenges posed by climate change

Climate change is already directly and powerfully impacting the earth's water system, posing substantial threats to ensuring safe water and sanitation for all. As its effects continue to escalate and accelerate, these will only worsen. This adds challenges for countries to achieve SDG 6. According to a 2021 survey of water leaders from 86 countries whose combined population exceeds 6 billion, the greatest perceived risk for water management was climate change. For 80 per cent of them, it ranked among the top three perceived risks. At the same time as it is threatened by climate change, the water sector is the key for improving climate resilience in communities and

[5] Contribution from the Government of Romania

ecosystems (Kerres et al., 2020). Water demand management, reduction of water losses, and reuse of treated wastewater are crucial to mitigating and managing the risks posed by climate change.

Water scarcity affects over 40 per cent of the global population and is only projected to rise due to climate change. Over 1.7 billion people are currently living in river basins where water use exceeds recharge (United Nations, 2022). Even major developing countries such as Türkiye still face existential water shortage challenges. When the annual usable water amount per capita in Türkiye is calculated using the address-based population data of 2017 published by TÜIK (Turkish Statistical Institute), it is estimated that this value will decrease to approximately 1.120 m3 in 2030 from its 2017 value 1.400 m3. Unless water resources are used more effectively and efficiently, Türkiye will become a water-scarce country during the 2030s.[6]

Increasingly severe floods and droughts are being brought about by climate change. As we have seen in 2022, these are now affecting all continents and are among the most critical events influencing the availability of water resources and hence the adequate supply of clean water for drinking and sanitation. Cameroon, for instance, has been facing an abnormal recurrence of extreme weather events including violent winds, high temperatures, long periods drought, and heavy rainfall, endangering human communities, ecosystems, and service provision.[7]

Rising water temperatures also create ideal conditions for bacteria and viruses to thrive, resulting in concerning surface water and groundwater contamination. The poorest countries suffer the most from this due to their lower freshwater body coverage (1.4% of land area on average) compared to developed countries (3.5% of land area on average) (Favre and Oksen, 2020). Worsening water conditions undermine efforts to reduce poverty, increase food security and develop a diversified economy.

Developing countries must strengthen efforts and commitments to address the challenges to water supplies resulting from climate change. Brazil, for example, has prioritized specific public policies and initiatives aimed at reducing losses in the water supply system in its fourth national communication to the climate convention.[8] It also crucial that national climate planners and decision-makers integrate water management into the climate responses set out in UNFCCC National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs) (Timboe et al., 2020).

[6] Contribution from the Government of Türkiye

[7] Contribution from the Government of Cameroon

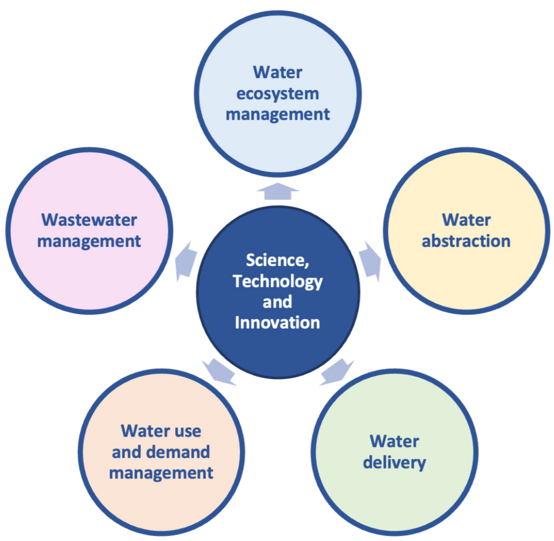
[8] Contribution from the Government of Brazil

3. Science, technology, and innovation for ensuring safe water and sanitation for all

Water science, technology and innovation is one of the longest standing human enterprises. Water installations represent some of the oldest forms of infrastructure in recorded history. A neolithic wooden water well found in Czechia has been dated to 5255BC while irrigation systems discovered in the Jordan Valley are thought to have been built in 6000BC (Wu, 2020; Sojka et al., 2002). These early innovations helped provide local water security, enabling the development of agriculture and human settlement that has become the basis of human civilization as we know it.

STI is pronounced in every part of the water value chain (see Figure 3), from surface and groundwater abstraction, to treatment for safe use, to effective reticulation to end-users, to return flows of polluted waters, to wastewater treatment back to stream, and all over again (Kerres et al., 2020). The different parts of this value chain correspond to the targets contained within SDG 6. Despite this, the global water community has generally not been a sufficient beneficiary of the STI knowledge that exists: the gap between research and development and widespread implementation of it remains significant.

Figure 3
The STI-water value chain



Source: Authors

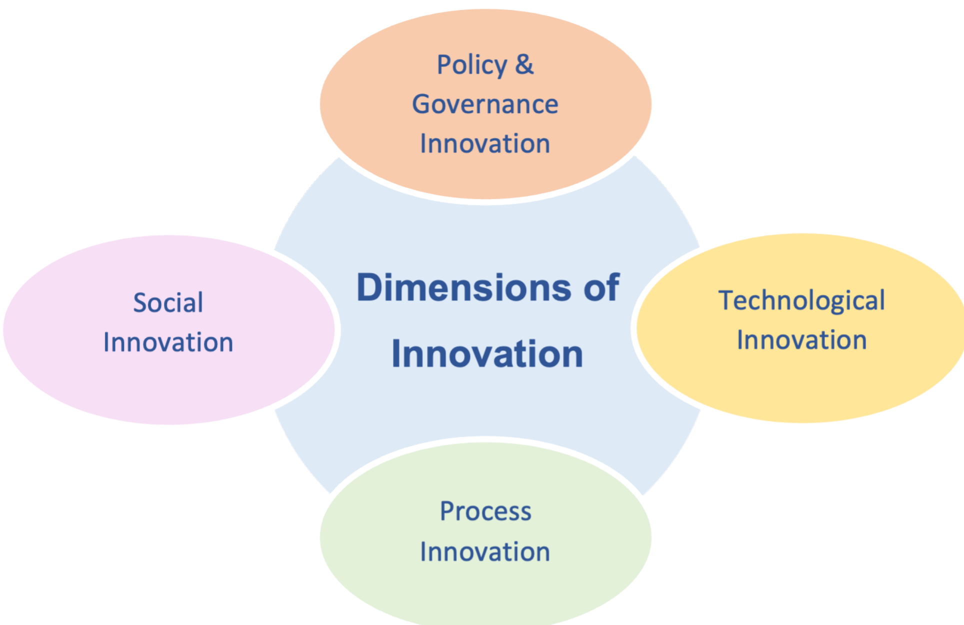
STI's contribution to achieving universal access to safe water and sanitation and SDG 6, can be divided into three phases. The first is analytical science which focuses on research and knowledge augmentation. The second is the development of solutions which attend to problems and improve the ways in which solutions are rolled out through technological invention and innovation. The third is the embedding and upscaling of solutions in the water value chain such that they become the dominant and improved way through which water and sanitation challenges are managed.

Figure 4
Contribution of the STI enterprise to safe water and sanitation

Source: Authors

Recognizing the wide spectrum of innovation is crucial. The general assumption is that innovation is primarily technological. Though technological innovation is an invaluable contributor to progress in water and sanitation and all other SDG6 sub-goals, alone it is insufficient. Where very good technological solutions exist, the achievement of real and lasting impact requires a wider spectrum of innovation: innovation in process, in policy and governance, and in social focus and outcomes.

Figure 5
Dimensions of innovation



Innovation in provision of water and sanitation similar to other types of innovation takes dimensions of (i) process innovation; (ii) technology innovation; (iii) social innovation; and (iv) policy and governance innovation.

Source: Authors

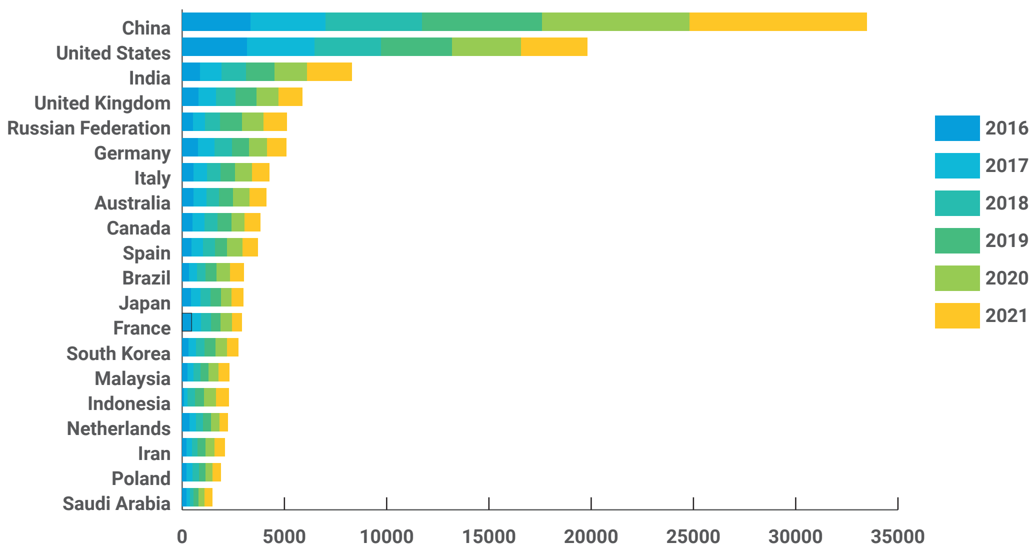
Process innovations are central to ensuring optimization in operations as well as critical inventions in water demand management as a key tool for water security. Social innovation recognizes that modern water management is about people and operates in specific social and cultural environments. Innovations in facilitating solutions co-designed with, and jointly owned by, communities which have a tacit appreciation of traditional and cultural knowledge have a better chance of becoming successful sustainable solutions. Policy and governance innovation is characterized by flexibility, data-driven decisions, and a willingness to adopt and help foster the implementation of proven innovations. It is key to enabling the rapid yet sustainable introduction of new solutions. The risk mitigation impact of good innovative policy and governance cannot be underestimated.

3.1 Scientific research and knowledge on water and sanitation

The scientific community has been highly productive, evidenced by prolific publication rates over recent decades. Analytical science is a crucial component of the knowledge required to address water and sanitation challenges and provides the bedrock solutions are developed on. Thanks to the scientific community's efforts, a substantial repository of accessible information and knowledge which is ready to be used to improve our water and sanitation systems can now be found in various journal publications and reports.

A global snapshot of the bibliometrics of water research over the 2016-2021 period shows global STI-water-related publications to be dominated by China and the USA (see Figure 6). It indicates that while publication rates are growing rapidly, they are concentrated in developed countries and advanced developing states. Almost 50% of the global publications in this domain are produced by the top 5 countries in the list (China, the United States, India, the United Kingdom, and the Russian Federation).

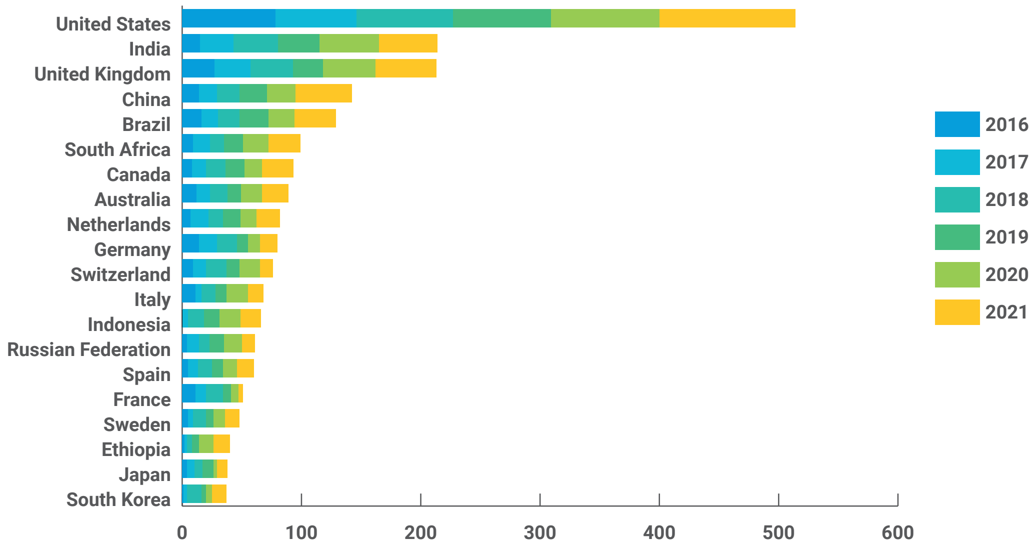
Figure 6
Top 20 countries by number of STI-water-related publications, 2016-2021



Source: UNCTAD based on SCOPUS

Compared with the water sector, the growth of publication of knowledge in the domain linking sanitation with science, technology and innovation has been modest. Globally, in 2021, there were only 754 STI-sanitation-related publications, with the United States, India, the United Kingdom, China, and Brazil the main contributors (see Figure 7). However, developing countries such as Brazil, South Africa, Indonesia, Ethiopia, have given comparatively more attention to STI-sanitation-related research, highlighting the urgent need to improve sanitation in these countries and ones in a similar position to them.

Figure 7
Top 20 countries by number of STI-sanitation-related publications, 2016-2021

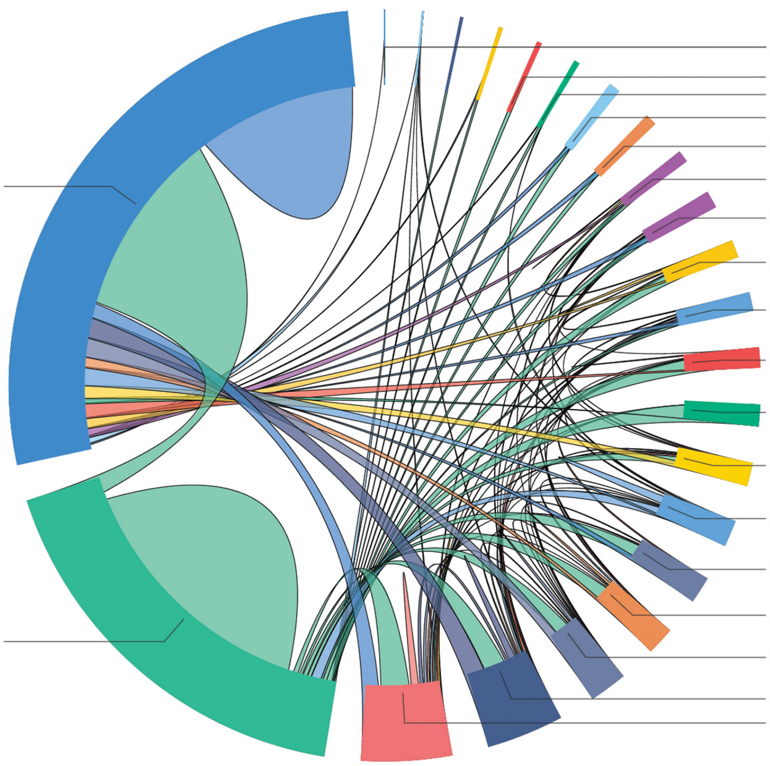


Source: UNCTAD based on SCOPUS.

Global imbalances in the pattern of production and consumption of knowledge products on STI and water are even more profound if we examine the knowledge flows illustrated in Figure 8. Developing countries like China and India are emerging as knowledge production centres, though their outward knowledge flows are not as prolific as those of traditional Western knowledge producing houses. The data confirms that countries with high water knowledge needs in the Global South are not significant knowledge producers. Possibly more concerningly, we also see that they are not prolific consumers either. This knowledge flow analysis indicates that even when there are significant knowledge production centres in the developing world, notably in China, India and Brazil, this knowledge is not being accessed by the larger part of the developing world – which is a central theatre of operation for SDG 6 and water and sanitation.

There are several reasons for this disparity in global knowledge flows between developing countries. The first is limited institutional and individual capacity to monitor and access new knowledge and knowledge products. A second relates to the limited nature of South-South knowledge networks and collaboration, with developing countries still counting on the developed countries as primary collaborators. In the latter case, researchers from developing countries often perform a junior partner role with less agency. The current state of affairs represents a missed opportunity for better and deeper international cooperation in the generation and the use of new knowledge and knowledge products.

Figure 8
Water-research related knowledge flows, 2012-2017



Source: (Mehmood, 2019)

The steepest inclines to be climbed to reach SDG 6 targets are in developing countries, particularly lower income countries. Yet these patterns of knowledge production suggest that it is driven largely, though not exclusively, by the developed world's challenges and consequently primarily addresses those. Despite this, the width and depth of the relevant knowledge produced by the developed world, combined with developing countries' relatively lower knowledge resources and the illogicality of dedicating them to producing knowledge that already exists establishes an urgent need to share the accumulated knowledge of countries like the United States, China, India, and the United Kingdom with countries facing high water knowledge needs in the Global South. International cooperation and multilateral forums can facilitate such knowledge transfer through initiatives aimed at increasing capacity building, funding, and ensuring that the development of science, technology, and innovation will achieve their potential to increase access to clean water and sanitation.

3.2 Technical and innovative solutions (TIS) and their implementation

Along with the high production of analytical science, advances in the development of technological and innovative solutions (TIS) in water and sanitation have made great strides over recent years. With rapid rates of production of new knowledge that is responsive to the genuine needs of people for safe water and sanitation, technology developers and innovators in both formal and informal sectors continue to work diligently be highly productive. The water and sanitation sector is a potential primary beneficiary of rapid advances in frontier technologies including the bioeconomy, big data and the Internet of things, and nanotechnology.

These technologies have the potential to powerfully assist us in the attainment of SDG 6 and its targets. The following sections present examples of implemented TIS contributing to the achievement of SDG 6, particularly its targets of universal access and integrated water resources management.

3.2.1 Accessibility of safe water and sanitation, including distribution and delivery

Access to clean water, notably in developing countries, is hindered by factors including the lack of adequate infrastructure, limited water resources, global warming, pollution in water sources, high-water stress due to excessive extraction, and wasteful behavior. However, different trends and challenges predominate region to region. Some areas in developing and least developed regions struggle to find adequate resources to access clean water and lack infrastructure or struggle due to water stress. In others, there may be plenty of water resources available, but major challenges related to obsolete infrastructure assets, excessive levels of water consumption, or problems with pollution and contamination.

Access to sanitation, on the other hand, presents a much more uniform picture: it is significantly less context-dependent and always requires above all the establishment of proper sanitation facilities. This can be costly and the best way of doing so –particularly when it comes to dealing with waste– varies depending on contexts, but less so than with water. Multiple currently available technologies and innovative practices can help address such water and sanitation challenges.

Innovation to address the availability and delivery of clean drinking water

The challenge of getting water services into underdeveloped, rural, remote, slums, and informal settlements presents a major problem. China has demonstrated a successful way to address water access in remote rural areas after recognizing that difficulty to access water is a key constraint to rural development in general and to women's progress in particular. Since 2000, the China Women's Development Foundation (CWDF) has rolled out the "Water Cellar for Mothers" project to address water shortage in poor and arid areas in rural China.

It is the first nationwide and women-specific water project in China. Its central focus was the construction of concrete water cisterns to store rainwater for use during dry spells. Additionally, centralized water supply facilities were built to ensure safe drinking water and provide villagers with easy access. By 2021, 139,900 cellars were built, supplemented by 1,941 centralized water facilities and 1,045 safe drinking water projects. The project covered 30 provinces, autonomous regions and municipalities and eventually afforded increased water access to 3.3 million people.[9] It has given women more time and energy to dedicate to education, upskilling, and economic activities to improve their financial condition. Thanks to the cellar project's water, many have been able to grow vegetables and raise poultry and livestock, improving their family income.

Approximately one quarter of the world's urban population live in slum areas (Habitat for Humanity, 2017). Kibera, in Nairobi, Kenya, is widely considered to be East Africa's largest slum. With its

[9] Contribution from the Government of China

estimated population of 250,000 within a peri-urban area of only 2.5 square kilometers, access to water and sanitation is a major problem. Most families in Kibera live on under USD 1 per day.

With buildings overlapping with one another, leaving only narrow pathways to navigate through the slums, classically ground laid water pipes are a virtual impossibility. As water provision from vendors and cartels becomes increasing unaffordable, the NGO, Shining Hope for Communities (SHOFCO) has developed an innovative process of water delivery using an aerial pipeline (Wesangula, 2016). This system was conceptualized as a circumnavigation of the complicated and costly logistical hurdle of distributing water across a settlement where space is at a premium.

The core concept involves piping water from the Nairobi Water and Sanitation Company into a 100 000-litre storage tank via an aqueduct composed of an aerial mounted pipeline, creating a water network capable of providing water access to 84,000 people. The idea was to enable access to water with a maximum 8-minute walk to vending points which is achieved through a networks of water kiosks, many built in partnership with a private sector partner, the mobile company SafariCom. While this is a state-of-the-art intervention in a country that is a global leader in water management, interventions at smaller more accessible scales are equally possible.

Figure 9
Shining Hope for Communities (SHOFCO) Aquaduct in Kibera, Nairobi

Photograph by Daniel Wesangula (Wesangula, 2016)

Swiss Fresh Water (SFW) has developed a small sized low-cost desalination system for salt or brackish water. It uses ultra-filtration, carbon filter and reverse osmosis filtrations and can rely on either solar power or the grid for its energy. It allows for the small-scale production of drinking water (4’000l drinking water/day) sold at a price 3 to 10 times cheaper than the mineral water sold in 10L bottles, depending on the area (peri-urban or rural). The system has been designed with easy use, maintenance and low energy consumption in mind. Sensor- and IoT-based remote monitoring technologies make it suitable for use in developing countries, notably in Africa. A 2012-2019 pilot project in the Sine Saloum Delta in Senegal, home to 225,000 people struggling to access clean drinking water due to the predominance of brackish and fluorinated water, has proven the concept’s capacity for success on a large scale. SFW set up more than 120 water kiosks on a franchise model in urban and peri-urban areas, around which small craft and service development centres have developed, generating more than 500 income-generating jobs.[10] Following its success in Senegal, SFW is seeking to replicate the model in West Africa, South America, and Asia through partners including REPIC.[11]

Similarly, in Kenya, GivePower, a non-profit organization that develops clean water and energy systems, is converting sea and brackish salt water into clean and healthy water. GivePower is using advanced filtration systems and new solar powered desalination technology to provide fresh water in Kiunga, a small fishing community of about 3.500 people located in an extremely dry area. Each solar water farm produces enough fresh drinking water for 35.000 people every day. Compared to most ground well systems, the GivePower solar water farm produces a higher quality of water over a longer period of time with no negative environmental impact.[12]

Another simple small-scale and reproducible TIS electronic payment for clean water through ATMs (automatic teller machines), as implemented in the Karatu District of Tanzania (Lawson, 2017). There, Water ATMs have been installed through a partnership between the NGO Catholic Relief Services, the Danish Water Company Grundfos, and the Diocese of Mbulu Development Department. The aim is to resolve water governance issues and increase access to clean and safe water. Similar projects are in operation across several African and Asian countries. This technological intervention addresses issues relating to governance, payment and security matters as the ATM are in strategic locations in neighborhoods and no physical money changes hands.

Water treatment to ensure water supply

Cities and towns in developing countries generally benefit from running safe potable water thanks to centralized water treatment plants that purify it to a potable standard before it enters the reticulation system. The same cannot be said for peri-urban slums and communities in rural areas around the world. An estimated 2 billion people lack access to safely managed drinking water at home (Centers for Disease Control and Prevention, 2022). With an estimated 80% of wastewater returning to stream untreated, risks of water borne diseases and harm due to chemical and other contaminants are greatly increased (UNEP, 2022). With a growing population and ever-increasing industrial activity producing ever-more wastewater, this risk is growing manifold.

While remarkable progress has been made to better water treatment through technologies and innovations using nanotechnology, ceramic filters, smarter process design, and higher energy and chemical use efficiencies, many parts of the world lack access to reticulation systems that use them. One important alternative solution is provided by Point of Use Systems (POUs) (Pooi and Ng, 2018). These use a combination of flocculation, coagulation, filtration, and distillation to deliver safe and clear water for consumptive and other uses. With increasing demand and the high costs and challenges that come with implementing classical centralized water treatment, POUs are finding increasing uptake even in developed countries (Wu et al., 2021). Point of use systems have been in use for centuries and indigenous knowledge of natural filtering systems and choices of clays for storage vessels are an important opportunity to combine new and older science for sustainable and trusted culturally acceptable solutions (see Box 2).

[10] https://www.swissfreshwater.com/en/la-machine/

[11] Contribution from the Government of Switzerland

[12] Contribution from the Government of Kenya

Box 2
Example of a Point of Use System (POU)

POUs increase access to clean and affordable water, particularly compact and portable POUs which are increasingly being relied upon to decentralize water treatment for drinking water and the treatment of wastewaters for recycling and reuse. One successful example of a POU is the Vulamanz Microfilter from South Africa. It uses a nanotech solution in a textile scaffolding, known as fabric microfiltration, to filter contaminants including suspended solids, colloids and bacteria without using water treatment chemicals (VulAmanz, 2022).

Source: UNEP, 2022

Water saving toilets

Toilet flushing accounts for 30 percent of household water consumption (Madzia, 2019). All sewered sanitation solutions require processing in water-based treatment plants. Waterless toilet technologies, on the other hand, generate substantial water savings, help avoid waterway pollution, and create opportunities by turning human waste into bioenergy or organic fertilizer for crops.

The Bill and Melinda Gates Foundation (BMGF) launched a global partnership campaign in 2011 to reimagine the sanitation value chain by using the best STI available to reinvent the toilet so as to provide new sanitation solutions appropriate for the 21st century context (Bill and Melinda Gates Foundation, 2020). A key requirement for candidate solutions was low or no water use so that systems were non-sewered. Local safe treatment of the waste was crucial, which in turn promoted solutions enabling waste beneficiation by creating opportunities for employment and business development.

This partnership has been extremely successful and has grown from China, India, and South Africa to include many more developing countries and some developed countries as well. Over 25 of the breakthrough waste-processing core technologies that make up a reinvented toilet, all developed in the past decade, are now being licensed to more than two dozen companies for production, testing, and commercialization (Doulaye Kone, 2021).

Reinvented toilets and installations represent solutions on two fronts: they show great promise as an accelerated solution to close the SDG sanitation deficit, and their low or no water use resonates well with most countries as water scarcity becomes an increasingly present phenomenon worldwide. They represent a key adaptation measure to a world experiencing increasing water stresses as climate change’s impacts are increasingly felt. Additionally, they offer a low-carbon alternative to classical sanitation, thus resonating with the quest to increase global climate resilience.

Figure 10
Water and energy saving toilets for girls in a school, Kenya

Source: Bill and Melinda Gates Foundation / Samantha Reinders

Portable toilets

Portable toilets have often been used as temporary toilets at events. However, the benefits of portable toilets, including lower or no water use and sustainable waste disposal, increase their attraction as a broader solution to be implemented to increase access to sanitation.

ECOLOO, a Swedish-Malaysian start-up which was a winner of UNWTO's SDGs Global Startup Competition, invented an odour-free, water-free, sewage-free, energy-free, and hassle-free portable toilet solution. It is easy to install, maintain, and can be used permanently or temporarily. It employs special formulated bacterial culture to treat and vanish human waste and transform the urine into natural liquid fertilizer.[13]

With sanitation deficiencies having a particularly heavy impact on women and girls, it is crucial that all sanitation TISs consider the gender dimension. In India, the TI Bus initiative provides public toilets specifically for women by housing them in refurbished buses. The TI Bus was created by Sara Plast, a social enterprise which took action to address the gendered sanitation crisis in the city of Pune where women lacked access to safe and clean public lavatories. The refurbished buses can be located using a mobile navigation application called Soch-O-Mat. The buses have buzzers to call trained female attendants, panic buttons, baby changing facilities, and sell menstrual products and provide healthcare information. They use smart toilet technology such as floor cleaning mechanisms, IoT-based waste management facilities, and feedback buttons.

Water and sanitation for smart settlements

In developing countries, sanitation and wastewater treatment systems are far from ubiquitous. There is therefore a need for easy-to-install sewage treatment facilities. In Malaysia, independent sewerage treatment plants (ISTP) were developed by a team of researchers from Universiti Putra Malaysia. The ISTP is a 360-liter modular wastewater treatment technology which treats wastewater to the country's highest regulatory standard for 7 hours discharging the treated water back into the water system. The "Smart Sanitation for Water Settlements" project was designed to tackle

[13] Contribution from UNWTO

pollution and reverse the degradation of marine and coastal ecosystems due to lack of sanitation and wastewater treatment in the Lok Urai water village near the Sabah Marine National Park. It involved the installation of 10 ISTP tanks with 10 residents trained to install and maintain them. The technology brings innovation where no sanitation and wastewater treatment systems are in place, with benefits for the environment and human health (Special Project with United Nations Environment Programme (UNEP), 2022).[14]

Ending open defecation

Ending open defecation is crucial to the successful implementation SDG 6's water and sanitation targets. It is a challenging task in many developing countries, particularly in rural areas, due to difficulties financing the construction of properly equipped toilets as well as a general lack of awareness by communities surrounding the health and environmental implications of open defecation.

However, India's experience illustrates that it is far from impossible. The Swachh Bharat Mission (SBM) combined modern technology and innovative governance with leadership commitments from the highest political level. The Indian government initiated SBM in 2014, aiming to end open defecation nationally within five years by constructing toilets at the public and household levels and enhancing waste management. The campaign effectively mobilized modern technology for comprehensive monitoring of construction progress and to avoid corruption. Every toilet built under SBM was mapped onto an integrated management information system to track real-time progress and was mandatorily geotagged to allow the public to locate them using Google Maps (Karelia and Bhaskar, 2018).

Within five years, over 95 million new toilets were installed across the country (Chaudhery, 2019). SBM has had extensive impacts: the number of people engaging in open defecation dropped from 550 million to 50 million (India Ministry of Drinking Water & Sanitation, 2019) and the number of deaths from diarrhea due to poor sanitation decreased from 140,000 in 2014 to 50,000 in 2018 (WHO, 2018).

Though much still needs to be done to engage that last mile of implementation and reinforce ODF behaviours, a number of studies have verified SBM's positive net across a range of indicators, notably an improvement in the population's health status (Dandabathula et al., 2019). SBM is arguably one of history's single biggest successes in terms of providing a basic service to a population.

Innovative Fecal Sludge Management (FSM)

Fecal Sludge Management (FSM) systems are integrated and decentralized systems for the safe treatment and disposal of wastewater and human body waste from dwellings and businesses close to their sources. In Thailand, they are being developed with support from the Gates Foundation. The stages of the FSM process involve the emptying, collecting, transporting, treating, and disposal of fecal sludge. The system thus engages multiple stakeholders to address fecal sludge problem using innovative solutions. A functioning FSM service chain requires strong awareness and understanding of the consequences of misconduct by households, fecal sludge collectors, fecal sludge treatment operators, related local government officers, and policymakers at local, provincial, and national levels.

Three innovative products are being developed in Thailand, namely Cess to Fit, the Solar Septic Tank, and the Zyclone Toilet. The "Cess to Fit" system is designed to be retrofitted into existing cesspool systems. The "Solar Septic Tank" collects solar energy and uses it to eliminate pathogens, enhance the biodegradation of organic matters, and produce better quality septic tank effluent. Finally, the "Zyclone Toilet" is able to separate solid and liquid waste using gravity and the cyclone concept. Key considerations in the development of innovation to improve the FSM process focus

[14] Contribution from UNEP

on designing technological solutions that enhance the user interface or reduce sludge volumes by creating better onsite collection and storage methods (Koottatep et al., 2021).

FSM also offers sustainable solutions by transforming sanitation waste into more valuable materials. Sanivation, a Kenyan social enterprise, is partnering with local governments to help meet growing waste processing and energy needs by transforming fecal sludge from septic tanks and pit latrines into biomass fuels. It designs, builds, and operates fecal sludge treatment plants whose biomass fuel sales cover operational costs, generating financial viability. Each plant ensures waste is safely managed, creates local employment, prevents environmental pollution, and saves trees by promoting biomass fuels.[15] This is a perfect example of how STI solutions at the water-energy nexus can have dual benefits.

Mitigation of and adaptation to climate change's impact on safe water supply

Climate disasters in the form of extreme weather events are becoming increasingly frequent across our planet. Climate change's impact on water, particularly by increasing the prevalence of droughts and floods, puts significant stress on both water supply and water quality. To address the grave challenges presented by climate change, hydrogeological approaches with a strong climatological dimension could generate important benefits.

Austria is exploring the combination of meteorological-climatological and geological-geophysical competences through its GeoSphere program. Geoelectric analysis measuring the electrical resistance of subsoil can inform surveyors about the latter's water content, allowing for lateral and temporal changes in subsoil water flow to be measured. Geoelectric analysis can be used wherever knowledge of subsoil water supply and its changes is relevant. This includes the demarcation of landslide areas, the development of early warning systems, groundwater exploration, the monitoring of flow movements (using fed-in salt tracers), monitoring of dams, and more. The intersection of weather and climate data with subsoil saturation data promises great potential for innovation, especially when assessing the effects of climate change on the future availability of groundwater resources.[16]

In India, the government implements the Water Technology Initiative (WTI) to promote technology development for the provision of water from sustainable sources; for the augmentation of water quality for specific applications; and for the recycling and reuse of water. The initiative has had a vast social impact and its field interventions have benefitted 200 000 people to date.[17]

Early warning systems are crucial in preparing responses for the natural disasters which have become more frequent due to climate change. In Latvia, the government has implemented an early warning system involving high technology and deeply integrated earth observation systems as well as mobile pipe flushing water flow devices for data collection on water flow, pressure, and turbidity, and for 3D river flood models capable of predicting flood threats 24 hours in advance.[18]

At local levels, low-tech innovative systems involving community participation with higher levels of community agency and effective partnerships are already proving to be highly impactful. A recent example is the Community Based Flood Early Warning System (CBFEWS) which has been established in an informal settlement or slum in eThekwini in KwaZulu-Natal, South Africa. It ensured zero loss of life in a community that lived on the banks of a river in an April 2022 'rain-bomb' event in the city.

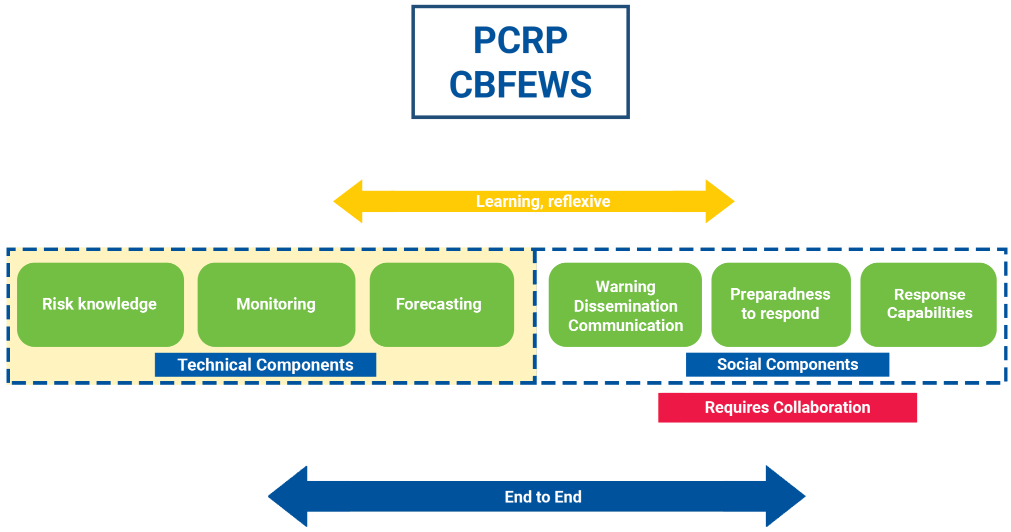
[15] Contribution from the Government of Kenya

[16] Contribution from the Government of Austria

[17] Contribution from the Government of India

[18] Contribution from the Government of Latvia

Figure 11
End to end community-based flood early warning system in the Palmiet Catchment Rehabilitation Project in Durban



Source: The Community Based Flood Early Warning System

The CBFEWS is an example of bottom-up innovation based on the co-production of knowledge in a local governance platform (state, university, civil society organizations, local Enviro-champs, and Quarry Road West community members). Real-time information from CBFEWS flood warning system includes municipal weather and river data, risk warnings translated by researchers, and on-the-ground conditions provided by community members. By providing residents of the informal settlement with real-time, accessible, and context-specific information, safe and life-saving evacuations are made possible in the event of floods.

Water-related disasters often have cross-border elements and challenges which require strong regional cooperation. On this front, in the United Nations system, regional commissions and several agencies have programmes to promote STI solutions to contribute directly to building resilience against water related disasters. For instance, the Economic and Social Commission for Asia and the Pacific (ESCAP) highlights regional cooperation through a space-based drought monitoring mechanism which provides timely and free access to space-based data. Relevant products and services as well as training and capacity-building support are provided to participating countries.

Similarly, The World Meteorological Organization (WMO) provides online information on extreme weathers (i.e., tropical cyclones, heavy rain and snow, thunderstorms) and aims to provide the entire global population access to early warning systems by 2027 (WMO, 2022). Meanwhile, the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) makes available space-based scientific knowledge and technologies for disaster management. The United Nations Office for Disaster Risk Reduction (UNISDR) remains the focal point in the United Nations system for the coordination of disaster reduction, seeking to ensure synergies among disaster reduction activities, including providing early warning system for flooding and droughts that affect water supplies at national and regional levels (UNCTAD, 2019).

Data gathering and forecasting for water security and sanitation

Inadequate water quality continues to pose major threats to human health. Water quality is ensured only if it is continuously monitored. Monitoring allows for the control of water characteristics, the identification of patterns and trends and emerging problems, the determination of whether pollution control programmes are working, the design of better pollution control efforts, and better responses to emergencies such as floods and spills. Traditional monitoring of water quality involves on-site sampling of water and subsequent laboratorial analyses. While this provides accurate measurements, it is costly, time-consuming, and indicative only of the situation at the points where samples are obtained. Alternative TIS offer important ways of ensuring water quality and safety while increasing efficiency and reducing the costs of doing so.

The information revolution has empowered policymakers by massively enhancing their capacity to understand the situations they seek to address. It can empower them to make more informed decisions while simultaneously enhancing governance through transparency and accountability.

The SIASAR joint initiative between several South and Central American states is an example of this.[19] The initiative establishes an up-to-date and verified information tool on existing rural water supply and sanitation services and increases transboundary cooperation in water among members. It is designed to be applicable by countries with similar rural water and sanitation systems (low levels of coverage, limited self-sustainability, little information, etc.).[20]

In most developing countries, rapid population growth without parallel development of urban water treatment infrastructure is challenging utility companies that are unable to maintain their systems properly. To tackle this problem, Egypt's government has established an online system to monitor pollution loads in wastewater discharge from major polluting enterprises. The system is expanded annually to ensure a strict control over the main wastewater dischargers in order to maintain the quality of ambient water in the main watersheds that feed the water treatment plants supplying the country with drinking water. The system eases burdens on competent authorities performing regular drinking and ambient water quality monitoring. It also facilitates the forecasting and management of potential incidents affecting the quality of watersheds and reduces intervention response times.[21]

Hungary, through its Water Science and Water Security National Laboratory, is seeking to broaden and deepen knowledge of its fluvial and lacustrine systems (e.g., River Danube, Lake Balaton, and Lake Neusiedl) by studying the complexities and interactions in their hydrology, hydrodynamics, morphology, water quality and ecology with the aim of informing the establishment of more advanced wastewater treatment technologies. This initiative has resulted in the development of a high-resolution 5G-based urban precipitation monitoring system encompassing the drinking water supply network alongside hydrodynamic models to control biological wastewater treatment processes.[22]

Water source protection is essential to ensuring water quality. China has developed a systematic technology-centred approach to protecting water sources and ensuring water quality. It comprises of (a) environmental surveys of water source zones; (b) analysis of pollution origins; (c) risk analysis; (d) water source zone delineation methods and plans; and (e) site delineation. At the water source, satellite remote sensing + APP technology is deployed, offering high-resolution detection, precise prevention, and control of environmental risk factors. It also generates detailed information on the spatial distribution of risk factors in water source zones. Through automatic water quality monitoring at water sources, real-time online early warning and monitoring of water quality are carried out

[19] Sistema de Información de Agua y Saneamiento Rural (SIASAR). See more at: https://globalsiasar.org

[20] Contribution from the Government of Dominican Republic

[21] Contribution from the Government of Egypt

[22] Contribution from the Government of Hungary

for specific pollutants including heavy metals and volatile organic compounds, rather than the conventional less-precise water quality control parameters such as pH and dissolved oxygen.[23]

The capacity to develop highly accurate models and indicators increases policymakers' capacity to anticipate the effects their decisions may or will have. For instance, UNRISD has funded and initiated the development of a context sensitive Sustainable Development Performance Indicator (SDPI) for sustainable use of water at the facility level. Published in February 2022, the indicator provides a low-cost and scalable method for establishing a sustainable water allocation for enterprises based on the hydrological, economic, and demographic contexts of their facilities. Its simplicity allows it to easily be upscaled and widely disseminated among enterprises, perhaps by governments, in the form of a digital tool.[24]

In a similar vein, social innovation was also the central focus of the partnership between the Development Bank of Latin America (CAF) and local NGO Agualimpia. They have partnered to deliver an innovative technological and social intervention to improve access to clean water in 13 rural villages in Peru (Agualimpia ONG, 2020). Besides using digital solutions to diagnose and identify gaps and prioritize and budget interventions in water and sanitation, the project adopted social innovations. It included social elements and community management in the optimization process, overhauled and improved social organizations involved in the provision of drinking water, and organized socialization workshops to foster conducive conditions for replication of the intervention. The partnership's project resulted in a 22% increase in the supply of water to the targeted drinking water systems (Agualimpia ONG, 2020).

3.2.2 TIS for integrated water resource management

Though water is a key driver of economic and social development, it is also fundamental in the maintenance and integrity of the natural environment. That said, it is only one of several vital natural resources, and water issues must imperatively not be considered in isolation. Integrated water resources management (IWRM) takes into account various users and uses of water, with the aim of promoting positive social, economic and environmental impacts at all levels. Governments and the private sector must manage and make difficult decisions on water allocation. They must apportion diminishing supplies between ever-increasing demands as demographic and climatic changes drive further water resource stress. The traditional fragmented approach is no longer viable: a more holistic approach to water management now essential. Technological and innovative applications enable different stakeholders, from water utilities and municipalities to businesses and citizens, to develop and implement more efficient data-driven water management practices and policies.

Hydrological observing system

Hydrological data describes hydrological cycles and can be used to better manage water resources by providing information on water quantity and quality, thereby enhancing delivery and research. The World Meteorological Organization (WMO) has developed the WMO Hydrological Observing System (WHOS) to collect reliable hydrometeorological data. This tool can be used for water resources planning and decision-making including for early warning systems on floods and droughts, integration into hydrological and climate applications and services, and for research (World Meteorological Organization, 2022). WMO is actively advocating the use of WHOS among National Hydrological Services and hydrological communities to share the evidence-based practices on water resource management.

The implementation of the tool in three pilot projects in the La Plata River basin by Argentina, Bolivia, Brazil, Paraguay and Uruguay, the Arctic basin, and in the Dominican Republic have proven its usefulness and effectiveness. These pilot projects have improved national and basin

[23] Contribution from the Government of China

[24] Contribution from UNRISD

expertise through capacity building efforts and have resulted in the production of more precise hydrometeorological products and services using big data and AI. The resulting platforms enable the visualization of data and allow users to download it, analyze it, and model it using a number of supported online tools and applications. This was achieved with a strong focus on interoperability that permitted the employment of already available data publication services. These efforts fall within WMO's attempt to promote open-data sources (Boldrini et al., 2022).

The water-energy nexus

The water sector is one of the oldest users and producers of energy. Hydropower, with its non-energy benefits, tends to be an investment of choice wherever possible. Most hydropower projects create water storage and flood control mechanisms and promote water-dependent development through agriculture, industrial production, and urban development. These energy generation projects' potential for good has increased substantively courtesy of STI progress.

Mobilizing the potential of this nexus, UNIDO set up a solar-powered slow filtration system to produce clean water, adopting Japanese innovative technologies in an Ethiopian rural area. The project focused on the provision of clean water through solar-powered water sanitation systems under conditions of equality and gender equity, on the development of community technical capacity to independently operate the systems, and the improvement of public health awareness. It also sought to build local industrial, engineering, procurement and construction capacity in order to strengthen their role in Ethiopia's water and sanitation sectors.[25]

In Latvia, renewable energy resources, notably solar power plants, have been used to produce electricity for self-consumption by water supply enterprises, reducing their energy expenses and thus reducing water prices and enhancing consumer interest in centralized water supply.[26]

TISs for the empowerment of women

Water and sanitation issues have an adverse and disproportionate impact on women and girls. The absence of drinking water in household premises generally causes women and girls to be tasked with water collection and treatment. TISs which bring water closer to the home empower women by freeing them from, or at least alleviating, this duty. The experience of the village of Ndombe (Mozambique), where a photovoltaic solar water pumping system was installed to enhance irrigation systems and increase crop yields, provides a case study of this. The better yield allowed women to sell produce to increase incomes as well as helping to improve their diets and reduce malnutrition.[27]

Building women's capacity is critical for better water management and for their empowerment. However, doing so in environments with entrenched traditional gendered roles is often challenging. The USAID Passages UPWARD project nevertheless shows it is possible to empower women by promoting their inclusion in water management decision making processes (USAID, 2021). Through a targeted series of workshops supported by appropriate materials, real success was observed in participating villages. Women's participation in decision-making and water management increased significantly. Other successes using different tools include the World Bank's intervention in Bangladesh where micro-financing and sanitation grants for household WASH facilities have had empowering outcomes. (World Bank, 2021). Upscaling and mainstreaming remain a challenge, but these represent encouraging starts.

In addition to generating higher levels of water security, TISs that improve access to water free women and girls from the burden of fetching water for the household, allowing them to be more active in the local economy or education. Empowered women in turn can enhance the development of their families, economies, and societies.

[25] Contribution from UNIDO

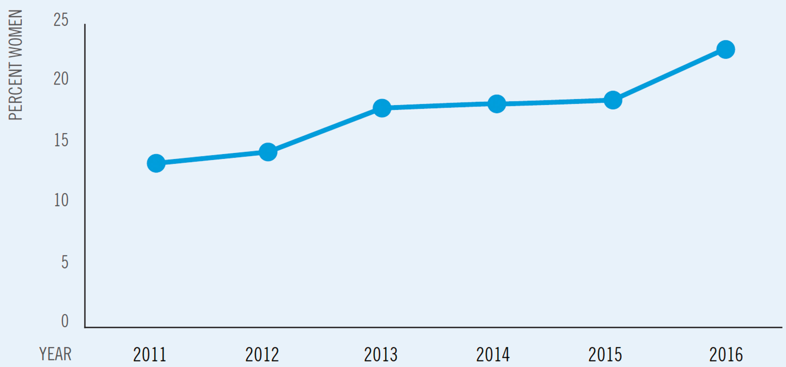
[26] Contribution from the Government of Latvia

[27] Contribution from UN Women

Box 3
Women in the water system

The World Bank report 'Women in Water Utilities breaking barriers" (World Bank, 2019) engages the key challenges for women in a major operational theatre of the water sector – the Utilities. While the participation challenges prevail, notable movement in women's participation is noted as illustrated in a graph from the report below.

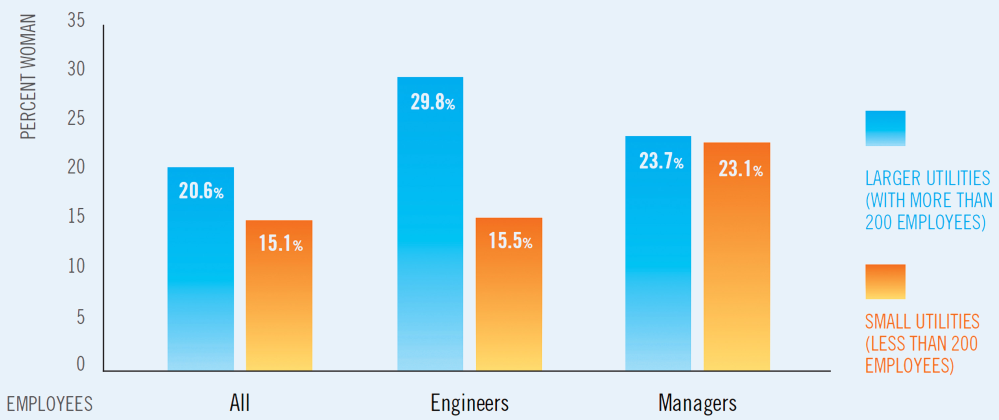
Figure 12
Trends in share of female workers in water utilities



Source: (World Bank, 2019)

Using data for the period 2011-2016, the report finds a steady upward trend in the share of female workers in the total annualised water sector workforce, albeit from a very low baseline.

Figure 13
Average share of employees in a water utility that are women, 2018-2019



Source: (World Bank, 2019)

The distribution of female employees indicates that larger utilities have a better capacity and more willingness to accommodate more female employees in the technical domains, for instance as engineers, compared to smaller utilities. At the management level, the willingness to recruit women to higher echelons is similar across large and small utilities.

The World Economic Forum Gender Gap Report 2022 estimates that gender gap has been closed by 68.1% but finds that at the current rate of progress it will nevertheless take 132 years to reach gender parity (WEF, 2022). Given the current situation in the water sector, its journey to parity is likely to take even longer unless catalytic transformation measures are put in place. Promoting girls' entry into education and the water industry's demand for female workers is likely the most effective remedy.

Sustainable water management for agriculture and food security

Water resource development and management are at the heart of sustainable growth and poverty alleviation. Water is linked to a multitude of pressing global challenges (World Economic Forum, 2022). It is an input to almost all production, being crucial to agriculture, industry, energy, and transport. It interacts with these systems through interdependence, constraints, and synergies – hence the value of nexus approaches at the intersection of these two sectors.

Agriculture accounts for 70% of water withdrawals worldwide, although this share varies considerably across countries. By 2050, world agriculture will need to produce 60% more food globally, and 100% more in developing countries (UN-Water, 2022). This means either an increase in the amount of water abstracted for irrigated agriculture at an opportunity cost for other uses, notably for drinking but also for industry, or an improvement in the efficiency with which water is used for agricultural purposes. Growing demand for water has already intensified competition for water resources by agricultural, industrial, and domestic users, leading to increased stress on aquatic and wetland ecosystems.

The agrophotovoltaics for Mali and the Gambia (APV-MaGa) project provides a case study in the use of STI in water management for food security. The project is exploring the potential for solar systems to improve access to water not only for drinking but also for agricultural purposes, and thus for food security. The project has explored how efficiency and sustainability in water usage can be maximized via intelligent systems incorporating smart sensors, microcontrollers, and the Internet of things. Real-time data access will aid the monitoring of weather, water demand and water allocation in the agriculture fields.[28]

More efficient and productive use of water is essential to mitigate water scarcity, increase food security and raise the incomes of smallholder farmers. The Food and Agriculture Organization of the United Nations and the Agricultural Water Partnership for Africa are developing evidence-based methods and best practices, and investing sustainable agricultural water management in Burkina Faso, Morocco, and Uganda. They link concrete efforts with national and continent-wide political processes (Swiss Agency for Development Cooperation, 2022).

Inefficient water use, water pollution, climate change and increasing global water demand put agriculture under pressure for commercial producers and smallholders alike. The Swiss Agency for Development and Cooperation (SDC) is building on successful experiences in this domain in providing 5.5 million CHF to support projects in Africa in ecologically sustainable water management in smallholder agriculture and food systems (Swiss Agency for Development Cooperation, 2022). Similarly, the Russian government has implemented Schemes of Comprehensive Use and Protection of Water Objects (SCUWO) by employing scientific and technological approaches to water management. The project constitutes the basis of the water management of water reservoirs located within the boundaries of river basins. SCUWOs are developed to assess the admissible anthropogenic load on water objects; identify the needs for water resources in the future; ensure the protection of water resources; and specify the main areas of activity to prevent the negative impact on water reservoirs.[29]

Social innovation for integrated water resources management

While technological innovation is of great significant in assisting countries to conduct integrated water resources management efficiently and effectively, social innovation is important and necessary to ensure this management is sustainable.

In Kenya, social innovation spurred the development of a participatory solution to improve the access to clean water in Nairobi's informal settlements through community bio-centers (Wamuchiru and

[28] Contribution from UNU-EHS

[29] Contribution from the Government of Russia

Moulaert, 2018). The initiative is grounded in bottom-linked governance through the collaboration of community-based groups and a human rights organization engaging in negotiations with state agencies for the satisfaction of water and sanitation services. At the same time, community groups carried out grassroots awareness-raising campaigns and mobilization workshops involving technical training and infrastructure construction, while members of the community were integrated into the water and sanitation service management.

3.2.3 Frontier technologies for water and sanitation

In many cases, simple and well-established solutions in water management can be used to address primary access to clean water and sanitation such as delivering drinking water solutions to communities. However, other aspects of management of water and sanitation may require new and emerging technologies. In this part, frontier technologies like drone, artificial intelligence, space application, and other technologies are discussed with respect to their potential for achievement of SDG 6.

Drone technology applications

Drone technologies can provide aerial views to assist in water and sanitation management, notably in the event of natural disasters. In Belize, drones have been used in the hydrological sphere to observe the spatial extent of flooding event. The country has also relied on drone technology as a reconnaissance tool when seeking to identify ideal locations for the placement of monitoring stations. Meanwhile, in Gambia, drones and Early Warning Systems have been used in for pre- and post-flood disaster efforts to help undertake long-term climate risk assessments and to update outdated and inaccurate topographic data.[30]

Drones are also readily used by some countries to monitor water quality and monitor infrastructure. In the Dominican Republic, the National Institute of Potable Water and Sewage (INAPA) relies on drone technology for data management, information exchange and decision making for the design, redesign, treatment, and maintenance of drinking water and sanitation systems. Similarly, Peru's National Water Resources Policy and Strategy proposes the use of drones to monitor and improve water quality and its efficient use due to their key advantages when it comes to providing observations of inaccessible areas of water bodies and vulnerable sites.[31]

AI, big data, Internet of things, and other technological applications

Data and digital infrastructure in water and sanitation management are catalysts for accelerating achievement and monitoring progress on SDG 6. In the Philippines, the Department of Science and Technology (DOST) is leading efforts to harness the power of artificial intelligence (AI) and machine learning to help curb water shortages in the east service area of Metro Manila.[32]

Another example comes from Internet of Things (IoT)-Enabled Sanitation Behaviour Monitoring in Indonesia where flow and motion sensors have been used to validate survey responses on handwashing after latrine use. Although survey responses showed relatively high levels of hand washing, the motion and flow sensors confirmed that the behavioural trainings were not having as much of an impact as reported through the survey results (Deloitte, 2020).

Improving water-use efficiency, demand management, and leakage control is one of the most urgent actions needed. Smart technologies that use big data, such as smart metering, can provide important support as they can trigger behavioral change of water users by providing them with real-time information and customized feedback. In Oman, the Water Leak Detection System was created in 2020 by the Oman Energy Centre to reduce the amount of waste in water resources to

[30] Contribution from the Government of Belize and Gambia

[31] Contribution from the Government of Peru

[32] Contribution from the Government of the Philippines

a minimum. The system takes measurements through autonomous smart meters to collect data on water usage. It has resulted in a 15% reduction in water waste.[33] Smart metering is a proven success: a 2020 study found that smart metering and automated leakage prevention systems installed in 40,000 households in India have helped save approximately 35% of water consumption on average (Viola et al., 2020).

In Latin America and the Caribbean, the Inter-American Development Bank has created Hydro-BID, an integrated and quantitative online system to simulate hydrology and water resources management using a combination of smart metering and the Internet of things (IoT). Under scenarios of change (e.g., climate, land use, population) the technology helps to evaluate the quantity and quality of water, inform infrastructure needs, and the design of strategies and adaptive projects in response to these changes.[34]

Nevertheless, most developing countries still require assistance and capacity building to capitalize on these technologies. It is thus key that developed countries support the development of infrastructure and human capacity building in using them. In this respect, Japan sets an example through its commitment to sharing technology and building capacities for countries that are willing to utilize technological solutions it has developed.[35] Among others, Japan uses AI and the Internet of things to support development and provide "Quality Infrastructure" in Asia and the Pacific, implementing climate change adaptation and mitigation measures with various infrastructure projects including "Quality Dams", "Quality Sewerage Systems", and "Quality Agricultural Infrastructure Improvement and Rural Development". Using AI and IoT, Japan has developed precipitation forecast and flood analysis technologies to visualize changes in local water-related disaster risks to enable the advanced operation of "Quality Infrastructure" installations.

Satellite-based solutions

Satellite data enables the development of innovative strategies to improve lives and accelerate sustainable development in many areas, water and sanitation key among them. Wider coverage of water quality observations can be obtained by satellite-based remote-sensing technology, which is suitable for near-real-time geographical coverage of water quality of inland freshwater systems, such as lakes, reservoirs, rivers, and dams, and which can detect lake eutrophication, light penetration, phytoplankton bloom, chlorophyll levels, turbidity, alongside other parameters.

Examples of good uses of such solutions are provided by Madagascar and Ethiopia. In both countries, a new methodology developed by the European Union's Joint Research Centre using satellite remote sensing to scan and identify high potential sites for the extraction of groundwater for on-the-ground geophysics investigations to perform more detailed studies has substantially improved drilling success rates. In Ethiopia, success rates rose from less than 50% to over 90%.[36] Similarly, in the Philippines, the Remote Sensing and Data Science (DATOS) Project developed a GIS-plugin to train and implement AI models to extract features from satellite imagery. The technology uses the agency's High-Performance Computing which can be used by public users from academic institutions as well as government agencies.

Regional Seas Conventions and Action Plans have adopted satellite-based methodologies to monitor chlorophyll levels. In 2021, the Northwest Pacific Region Environmental Cooperation Centre (NPEC) successfully developed the 'Global Eutrophication Watch' for mapping coastal eutrophication on a global scale using satellite remote sensing. Eutrophication is an emerging global issue associated with increasing anthropogenic nutrient loading. The methodology applied in the Global Eutrophication Watch is part of the Common Procedure for the eutrophication assessment

[33] Contribution from the Government of Oman

[34] Contribution from the Inter-American Development Bank (IDB)

[35] Contribution from the Government of Japan

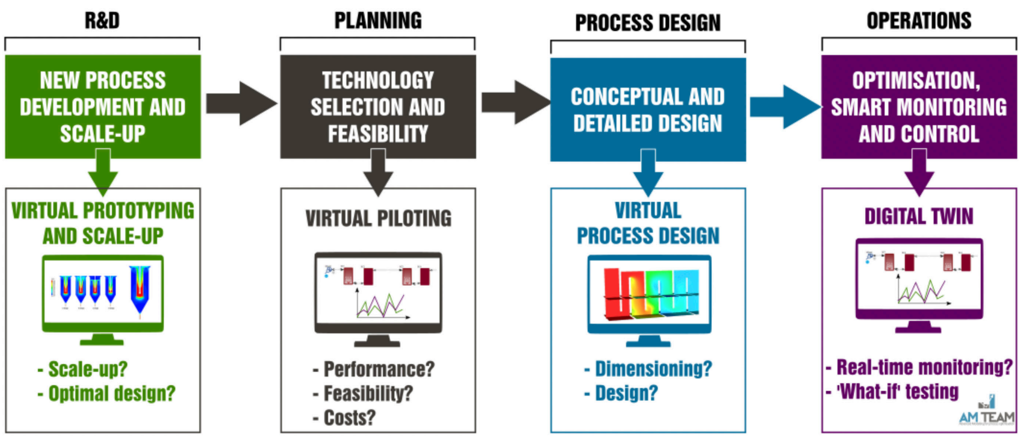
[36] Contribution from WHO

of the NOWPAP Special Monitoring & Coastal Environmental Assessment Regional Activity Centre (CEARAC). It will produce an interactive map of potential eutrophication area over the global ocean to help the NOWPAP Member States and countries around the world to manage eutrophication and report their progress under the 2030 UN Sustainable Development Agenda.[37]

Digital twinning

Rapid improvements in frontier technologies have led to the deployment of a range of technologies from this toolbox to help overcome scarcity, improve safety, enhance reliability and efficiency in the provision of services through real-time management and monitoring of water and sanitation infrastructure and operations, and by providing detailed and useful data and analytics. One interesting case study comes in the form of intelligent water management through digital twinning. Digital twinning refers to the concept of creating a virtual twin of a real asset. The Changi Water Reclamation Plant in Singapore is just one example of facilities which have recently completed a digital twin (Jacobs, 2020). These virtual duplicates of installations are used in conjunction with real-time monitoring and enable intelligent and dynamic management, the simulation of scenarios for business continuity and process optimisation, and the testing of interventions in the event of emergencies or upgrades.

Figure 14
The technology lifecycle and the use of digital twin model in the water industry



Source: (Audenaert, 2022)

3.2.4 Translating STI into real world impact

Despite the availability of vast amounts of scientific knowledge, water and sanitation practitioners generally either don't find the knowledge accessible or find that it is not in a sufficiently usable form to inform their decision-making. In general, the existing and available knowledge is spread unevenly across the innovation value chain: technical and scientific knowledge about technological possibilities and the functioning of the water system is extensive while practical knowledge in the domains of implementation, upscaling, commercialization, and impact is disproportionately lower.

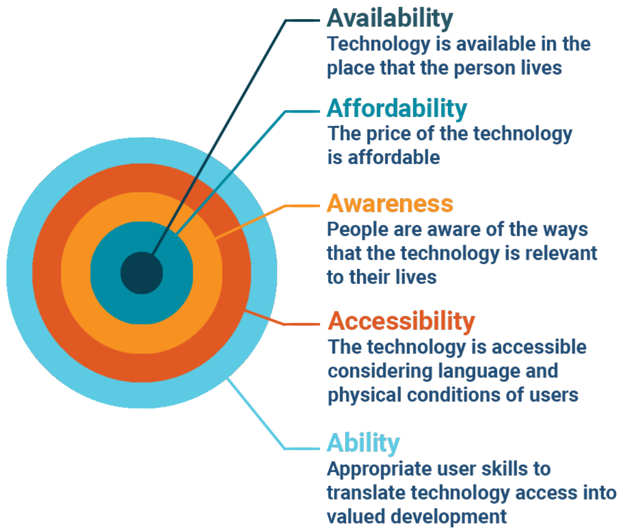
A key challenge is the lower availability of knowledge solutions closer to the implementation phase. Many factors may influence this, including the higher costs of innovation projects, the difficulty of attracting potential investment partners due to the higher risk profiles of new solutions, and a lack of capacity to support new solution platforms. It is also important to recognize the general market failure wherein new solutions supported by excellent analytical science which should be

[37] Contribution from UNEP

successfully implementable encounter the challenge of the 'Valley of Death' phenomenon.[38] There is a need for investment in the 'science of implementation' to examine accelerated mechanisms to harvest the solutions developed by the STI enterprise with higher frequency and regularity as the world's water and sanitation challenges become increasingly 'wicked' problems.[39]

One of the most critical aspects of the implementation of scientific knowledge or technological solutions addressing water and sanitation challenges is access: if a solution is not accessible it is not useful. Access can be considered to comprise a combination of "five A's": availability, affordability, awareness, accessibility, and ability for effective use (see Figure 9). Practical implementation of technological solutions thus first needs to do the mundane work of assessing and addressing the solutions' non-tech barriers to access. A solar-powered water pumping system, for instance, is of little use if it is too expensive, if people are not aware of its existence, or if it must be operated by a trained individual where no training is given. Access to technology can also be restricted by social norms (e.g., for women, ethnic minorities, etc.) or people who lives in geographically remote area.

Figure 15
The 5As of technology access



Source: (UNCTAD, 2021)

A second factor limiting implementation is the failure to recognize that water and sanitation problems are inherently trans-disciplinary and thus require multidisciplinary solutions. Even where solutions are completed from a science and engineering perspective, behavioral, cultural, policy, governance and other challenges can become obstacles to implementation. While physical science and engineering toolboxes are crucial to finding and creating solutions, their implementation and sustainability rely heavily on social science, economic and governance expertise, interventions, and strategies. A capable 21st century water team must possess knowledge and science-based solutions in these domains, but also requires skilled non-technical contextual expertise which helps ensure successful implementation.

[38] The 'Valley of Death' is a term used by practitioners in the innovation space to describe situations wherein working prototypes and concepts which by all considerations address the problem they were designed to solve and should be implementable nevertheless fail to make the leap to implemented solution (Klitsie et al., 2019).

[39] A wicked problem is a problem that is difficult or impossible to solve because it is a symptom or result of multiple, contingent, and conflicting issues. Interdependencies mean that the effort to solve one aspect of a wicked or complex problem may reveal or create other problems (Ramalingam et al., 2014).

Alongside the more operational level factors relating to access and multidisciplinary considerations, a reframing of how we think about water and sanitation at the macro level is also in order, requiring us to move beyond the paradigms of provision, treatment, and disposal as isolated elements. Instead, policymakers and water and sanitation stakeholders should take a step back and consider how their interventions fit into nexus and circular economy approaches to the problems they seek to address, and, whether these interventions might benefit from being adapted in line with them.

It is increasingly clear that embracing the connectivity between water and other sectors is essential to the development of sustainable and efficient solutions with multiple beneficiaries. It is also true that a failure to sufficiently appreciate the inter-dependencies of different sectors may lead to positive outcomes in one sector with unintended (and sometimes more significant) negative consequences in others. A nexus approach helps to mitigate this while also raising the possibilities of attracting a larger investment community and benefiting from more attractive cost-benefit ratios. This concept is not new in the water sector, and it has gained a reputation over time as representing a key building block to socioeconomic development. The water-energy-food nexus, a major strategy to ensure global food security alongside enhancement of water and energy access and security, is a particularly important example of this (FAO, 2014). Water-centered nexus approaches with other sectors are fundamental to the implementation of STI to achieve SDG 6 in water and sanitation while simultaneously contributing to the achievement of other SDGs such as zero hunger, clean energy, climate action, and partnerships for the goals.

Using circular economy approaches to water and sanitation allows us to move beyond relying only on freshwater resources in the water sector. Appreciating that adequately treated wastewater resources can be used for a wide range of applications, notably in agriculture, will go a long way to addressing water scarcity. In the context of growing water stress due to climate and demographic change, moving beyond the freshwater paradigm is key to making the most of limited water resources and managing them such that competing needs can best be met. The water sector has not yet been systematically included in high-level circular economy strategy discussions despite the opportunity circular approaches provide to recognize and capture the full value of water (Anna Delgado et al., 2021). Given the relative ease with which water can be returned to its original form (compared to other resources such as plastic), it would be a missed opportunity not to seek to maximise our ability to do so. These approaches however do necessitate distinct financial, institutional, environmental, technical, social and health conditions so as not to disrupt water networks and the communities and ecosystems that rely on them. Innovative water management and governance requires as much attention as infrastructure receives.[40]

[40] Contribution from the International Water Management Institute (IWMI)

4. Knowledge and technology sharing to effectively address water and sanitation challenges

In recent years, knowledge sharing has assumed the same level of importance as financial and technical assistance in the global development agenda (Janus and Karp, 2019). This is also the case when it comes to addressing water and sanitation challenges wherein the goal of achieving universal access to water can only be achieved if stakeholders from different sectors and different backgrounds come together in an inclusive way and find collective solutions to the challenge (See Box 4). The sharing of insights and learning from the experience of others is also important for enhancing the quality and efficiency of the formulation and implementation of water supply and sanitation initiatives. At the same time, enhancing capacities and competencies at all levels, including leveraging and building on traditional community knowledge, is crucial to effectively address water and sanitation challenges.

Stakeholders in the sector already understand this need. A range of global partnerships, platforms, and cooperation models have been set up under North-South and South-South, and triangular regional and international cooperation not only to support access to STI but also to enhance the knowledge-sharing that fosters the scaling up of good practice domestically, and inspires replication and adaptation of successful technological, social, and financial innovations internationally. The focus of these platforms and networks includes but is not limited to facilitating learning among countries and among public and private actors in the water and sanitation sector, sharing traditional and scientific knowledge, enhancing capacity, raising awareness, reinforcing the science-policy interface, and encouraging effective partnerships.

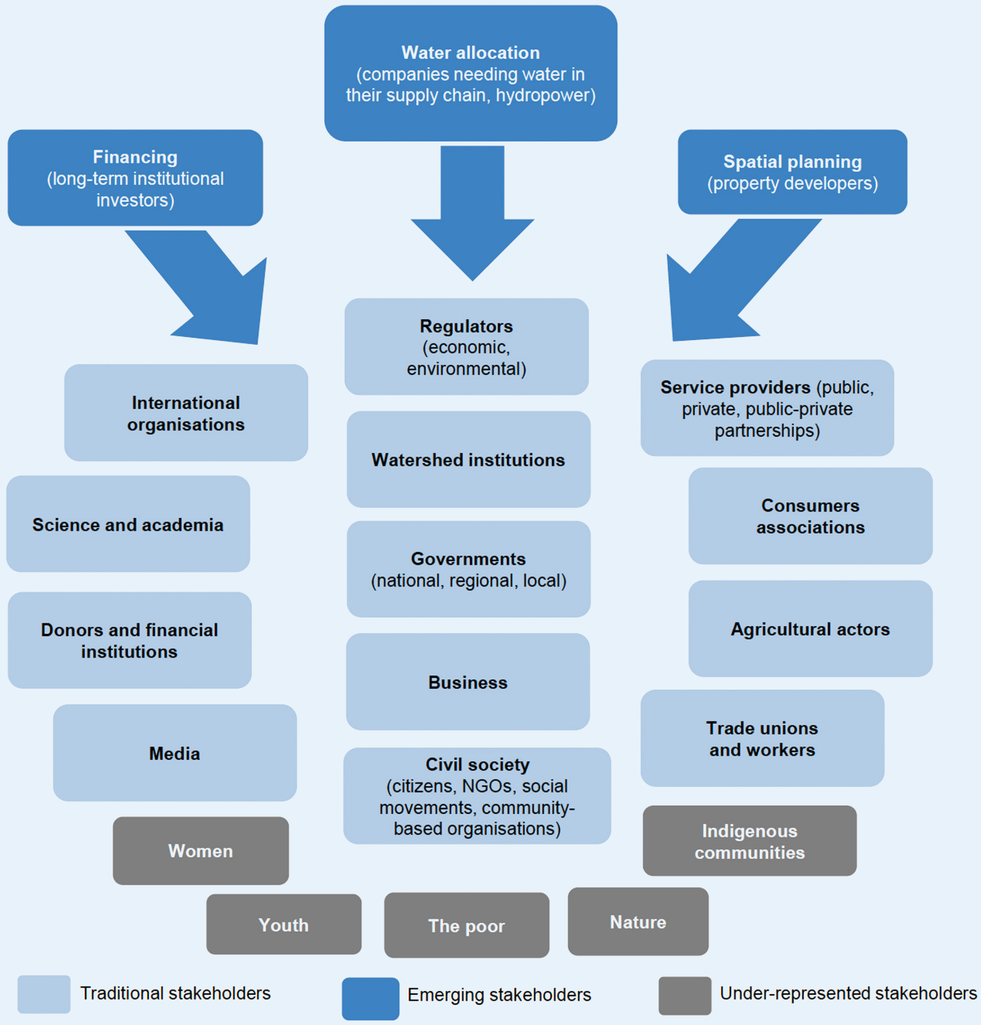
Several actors including multilateral organizations, development agencies, and dedicated water and sanitation networks have taken an active role in developing and promoting these platforms and networks. Usually, these platforms involve partnerships and combine a web platform with an extensive network that may reach from global to local level (UN-Water, 2015). They also share knowledge and build capacity through their own programmes.

Box 4
The role of the various stakeholders in water and sanitation management

Ensuring water and sanitation for all will require greater multi-stakeholder efforts. Water supply and sanitation management cuts across hydrological and administrative boundaries and involves multiple stakeholders, from end users to local and national authorities, regulators, and civil society at large.

Balancing the competing demands for water resources will have the greatest chance for success if undertaken at the relevant scale, inclusive of, and resonating with, all stakeholders (OECD, 2014). The number and type of actors varies across countries and across the public, private and third sectors of countries based on local context (see Figure 16). As mappings of international and national water governance frameworks in a range of countries demonstrate, stakeholders involved in decision-making and implementation processes related to water and sanitation vary across countries and across water governance functions from policy making, regulation and water resources management to service delivery and financing, and across national, intermediate and local levels (Human Right 2 Water, 2021: 2).

Figure 16
Major stakeholder groups in the water and sanitation sectors



Source: (OECD, 2015)

4.1 Multilateral organizations

Agencies of the UN and multilateral development banks collect resources and promote knowledge and practices, including those of STI, not only from their programmes but also from the global community. The problem of water and sanitation is an international issue, therefore, the UN is well placed to play the role of main outlet for debating and achieve agreements, and international cooperation should be strengthen to contribute to the development of infrastructures, capacity building in the area of water management, climate change adaptation, and technology transfer.[41] UN-Water, which comprises over 30 UN agencies, has the broadest thematic scope, sharing its own experiences as well as those of others. In collaboration with partners, it runs the UN-Water Activity Information System (UNW-AIS), an online platform where information on water-related projects and learning initiatives are presented and shared. They include UNICEF, UNESCO,

[41] Contribution from the Government of Cuba

UNDP, UNEP, UN-Habitat, Office of the United Nations High Commissioner for Human Rights (OHCHR), UN Department of Economic and Social Affairs (UN DESA), and UN Refugee Agency (UNHCR), and UNCTAD.

The UN Commission on Science and Technology for Development (CSTD) acts as a multilateral platform dedicated to science and technology for development in the UN system, where countries can share their lessons and best practices in leveraging STI to address water and sanitation related challenges they face. Additionally, the CSTD promotes international cooperation through technical assistance programmes to help developing countries, in particular least developed countries, small island developing countries and land-locked developing countries to access knowledge and technology that other member States are willing to share.

The World Summit on the Information Society (WSIS) Forum and other WSIS-related processes and activities have been providing a platform to share knowledge and information, promote best practices in all segments of life, including matters of sanitation and safe water. Co-organized by ITU, UNESCO, UNDP, and UNCTAD, has created meaningful WSIS Action Lines and SDGs, including one for SDG 6 that links with WSIS Action Lines on access to information, capacity building, ICT applications e-Science, and cultural diversity and local context.[42]

The Word Bank administers the Global Water Security & Sanitation Partnership (GWSP) that supports countries to meet the targets related to water and sanitation under the Sustainable Development Goals, particularly those of Goal 6. GWSP provides countries, other development partners, and World Bank staff with global knowledge, innovations and country-level technical support while also leveraging World Bank Group resources and financial instruments. Its mandate covers water supply and sanitation, water resources management, and water in agriculture and a broader range of themes related to inclusion, resilience, financing, institutions, and sustainability which has allowed learning and sharing on a range of topics relevant to water and sanitation including climate change; inclusion; urban sanitation; service provision in situations affected by fragility, conflict, and violence; and water supply, sanitation, and hygiene in healthcare (World Bank, 2021).

4.2 Development agencies

A number of countries focus on water and sanitation under their international and bilateral cooperation agenda. Consequently, a range of development agencies focus on knowledge and technology sharing, with knowledge sharing based both on their own experiences from development projects and in knowledge centres. Development actors such as the UK Foreign, Commonwealth and Development Office (FCDO), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Swedish International Development Cooperation Agency (Sida) facilitate the sharing of knowledge and lessons through their publication hubs and their programmes.[43]

But the capacity to share important knowledge and technology is not limited to developed countries: South Africa, for instance, through its Water Research Commission (WRC), has engaged deeply with multiple international partners to share its extensive expertise in water and sanitation.[44] In some situations, South-South knowledge sharing may even be more productive given deep knowledge and experience of challenges that are specific to the developing country context.

Another example is cooperation between the Mexican Institute of Water Technology (IMTA) and the Dominican Republic's National Institute of Potable Water and Sewage (INAPA) to provide water

[42] Contributions from ITU

[43] In the case of the FCDO, this hub is called Research for Development Outputs.

[44] Contribution from the Government of South Africa

and sanitation in rural and marginalized communities. IMTA trained INAPA staff in the adoption of technologies for the collection, treatment, supply, consumption, and disposal of water.[45]

The United States Agency for International Development (USAID) has programmes and a dedicated knowledge platform. It runs a knowledge platform called Globalwaters.org that serves as a knowledge hub for its water security, sanitation, and hygiene activities. Examples of its programmes devoted to generating and sharing knowledge and evidence to influence policy and practice both include the Water, Sanitation and Hygiene Partnerships and Learning for Sustainability (WASHPaLS). WASHPaLS identifies and shares best practices for achieving sustainability, scale, and impact of evidence-based sanitation interventions (USAID, 2021).

In Kenya, the World Bank has supported sanitation projects in Nairobi to provide greater water and sanitation access for people in urban settlements, especially for the low-income residents.[46] Water is also a priority sector in technical assistance programmes in Africa, offered by the Swiss Agency for Development Cooperation. Concrete activities have been undertaken through Swiss Fresh Water in West and Central Africa.[47]

Regional initiatives also play important role in ensuring access to safe water and sanitation. For example, Belarus has benefited from the international and regional cooperation in this specific area through the EU Water Initiative Plus (EUWI+) for the Eastern Partnership Programme, as well as in partnership with the UNECE and WHO Regional Office for Europe and with the use of mechanisms of the Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Through the regional initiatives, Belarus has been intensively participating in topical national and regional reviews and capacity-building activities.[48]

Some donors, such as the Netherlands, have directed their contributions through public private partnership initiatives. The Netherlands Water Partnership is now a networking platform of companies, NGOs, government agencies, knowledge institutions and other entities in the Netherlands that actively engages in sharing knowledge and expertise from the Dutch water sector. Combined with the Netherlands Enterprise Agency (RVO), it is implementing a Water Support Programme which provides expert advisors to share policy and financial knowledge with 10 partner countries (Netherlands Water Partnership, 2022). Furthermore, in partnership with the government of India, the Netherlands supports three Indo-Dutch bilateral consortium projects under the Bilateral call on Cleaning the Ganga and Agri Water Nexus, focusing on the Hindon sub-basin region. The supported consortia are led by premier Indian and Dutch research institutions engaging in collaborative research studying the impact of agriculture on water quality and quantity in the Hindon basin of the Ganga river system.[49]

Besides donor countries, regional development banks such as the Asian Development Bank (ADB), the African Development Bank (AfDB) and the Inter-American Development Bank (IADB) support knowledge sharing and capacity building. For latter's Latin American and Caribbean Water and Sanitation Observatory (OLAS) is a digital platform that compiles qualitative and quantitative information; technical, institutional, and regulatory documents on the water and sanitation sector for each country and at the regional level; and a research and development network. Similarly, the ADB's Asia and the Pacific Water Resilience Hub is an open, online platform that brings together water experts, policy makers, resource managers, and utilities to facilitate partnerships, provide training, develop and share knowledge products, and facilitate innovation in the sector, tools, data, and digital technology.

[45] Contribution from the Government of the Dominican Republic

[46] Contribution from the Government of Kenya

[47] Contribution from the Government of Switzerland

[48] Contribution from the Government of Belarus

[49] Contribution from the Government of India

4.3 Water and sanitation actors' networks

Several actors and networks with global, regional, and sub-regional focuses act as knowledge centres and active hubs of exchange for policy makers, utilities, and practitioners. Besides facilitating capacity development, some of these networks also lead on advocacy to enhance political commitment and governance to address water and sanitation challenges as well as to promote participation of disadvantaged and vulnerable groups in decision-making on water and sanitation issues. Partnerships and networks with such a focus include the Sanitation and Water for All (SWA) partnership, Global Water Partnership (GWP), World Water Council, Women for Water Partnership (WfWP), and the Water Action Hub.

The Water Action Hub, for instance, seeks to raise awareness, catalyze collaboration, and scale critical lessons on water sustainability and climate resilience through collaboration and knowledge sharing. Likewise, the WfWP is a partnership of women's organizations and networks from around 134 predominantly low and middle-income countries that provides knowledge exchange and learning platforms alongside regional workshops and peer-to-peer support.

STI-based initiatives are an increasingly central focus among water and sanitation actors as they seek to effect better regional water governance. The Kumamoto Initiative for Water, a regional Asia Pacific example, launched at the 4th Asia Pacific Water Summit 2022. It uses the Asia Pacific Climate Adaptation Information Platform (AP-PLAT) to advise the development of climate resilient quality infrastructure.[50] Similarly, the transnational and multidisciplinary Danube River Regional Resilience Exchange co-ordination and support action network, which seeks to strengthen flood resilience in the Danube region, presents a regularly updated RDI Roadmap highlighting promising innovation opportunities for its Partners.[51]

Innovation in the form of institutional and financial mechanisms is at the heart of the Latin America Water Funds Partnership (Allianza Latin Americana de Fumdos de Agua) as it promotes public-private participation in the conservation of watersheds to improve water security. With core partners,[52] it now has 26 funds operating in several Latin American countries including Brazil. Columbia, Cost Rica, Ecuador. Mexico and Peru and has benefitted over 105 000 families and has leveraged USD 240 million in Green infrastructure.[53]

Beside these major global networks, examples of successful smaller-scale international cooperation networks seeking to strengthen STI capacities are plentiful. One of these is the Transformative Innovation Policy Consortium, whose nine members are China, Colombia, Ghana, Finland, Kenya, Norway, Senegal, South Africa, and Sweden. It brings together science, technology and innovation researchers, policymakers, and funding agencies from the above countries with the aim of giving substance to a new framing for STI policy which it terms "Transformative Innovation Policy" (TIP). It seeks to conduct largescale policy experimentation: for instance, in South Africa, it has positioned two big water sector projects as strategic niche global experiments in innovation in sanitation and ecological water infrastructure security.[54]

Others can be found within the European Union's Horizon Europe scientific research initiative, co-funded by the European Union and several third countries. The Water Security for the Planet (Water4All) partnership aims to reduce water stress, better protect water resources, and ensure the adaptation of water resources to global changes by 2030. The AQUACOSM-plus project is an example of an innovative project benefitting from Horizon Europe funding as it seeks to advance

[50] Contribution from the Government of Japan

[51] The InterAmerica Development Bank (IDB), the FEMSA Foundation, the Nature Conservancy (TNC), the Global Environmental Fund (GEF), the International Climate Initiative (IKI) and the German Government.

[52] Contribution from the Government of Hungary

[53] Contribution from the Inter-American Development Bank

[54] Contribution from the Government of South Africa

mesocosm-based aquatic RI by integrating the leading mesocosm infrastructures into a coherent, interdisciplinary, and interoperable network covering all ecoregions of Europe.[55]

There are thus multiple initiatives facilitating knowledge sharing. However, in order to accelerate our progress in the Decade of Action with the Global Acceleration Framework's five pillars to achieve SDG 6 by 2030, there is a need to take it to another level and facilitate much higher levels of technology access, knowledge transfer and capacity and capability building, and to make such opportunities better structured, more organized, and less haphazard.

[55] Contribution from the Government of Türkiye

Policy Recommendations

Water and sanitation are basic and essential human needs. Since 2015, the General Assembly and the Human Rights Council have recognized both the right to safe drinking water and the right to sanitation as closely related but distinct human rights. SDG 6 has taken a broad and integrated approach to addressing the issues of water and sanitation, going beyond simple access to these services, with a view to ensuring the sustainability of water supply and good sanitation services.

This issues paper has examined how countries, developing ones in particular, can mobilize innovative STI solutions to address challenges in meeting the targets of SDG 6 on water and sanitation. These include improving access to and delivery of safe water, increasing the quality of water treatment, and making general advances in water and sanitation management. The process can be accelerated not only through scientific and technological approaches, but also through other forms of innovation, including social innovation, innovative policy or governance, and enabling laws that encourage practitioners and service users to find effective solutions. A number of policy considerations have the potential to assist countries in their efforts to harness science and technology in ensuring access to safe water and sanitation for sustainable development.

In this regard, national governments, particularly from developing countries, are encouraged to:

Cultivate and empower local innovation ecosystems.

A functioning local innovation ecosystem requires public and private actors to build technology acceptance, and, given the increasing use of digital tools, the capacity around digital mindsets and skills to use them. When choosing technology and innovation to ensure safe water and sanitation for the population, consideration should be given to the economic and geographical conditions in target communities as well as their ability to operate and maintain the interventions. Given the acute and widening SDG financing gap, a level of priority should be allocated to STI actions that can ensure value for money.

Develop close partnerships between practitioners and users, with a focus on community involvement.

Water and sanitation management requires a fruitful partnership between practitioners and users. Water governance is key to water security. Building the agency and capability of all actors, in particular non-state actors and vulnerable and marginalized groups including women, youth, disabled and indigenous peoples is of paramount importance. Governments and local authorities should encourage and assist the growth of grassroot- and community-led participatory initiatives to strengthen local ownership of water and sanitation services and enhance water governance by bringing practitioners and users together. In doing so, they should engage with community groups including indigenous and youth groups, human right associations, and environmental organizations, and foster collaboration among them.

Prioritise the development and distribution of modular, off-grid, decentralized, and low-tech solutions.

Developing countries often do not have the means to access complex and costly technology to provide clean water and sanitation. Nevertheless, evidence has shown that some recent developments in water and sanitation services can provide cost-effective solutions. To minimise water losses and waste, countries must accept the value of, and transition to, water-smart technologies such as waterless and low water use toilet systems, more efficient irrigation, technology-based optimisation of industrial water use, and real-time operations and maintenance. Solutions with one, more, or all of these characteristics can be particularly helpful in addressing water and sanitation challenges in remote communities and informal settlements.

Transform infrastructure and service delivery for gender equality.

Limited access to water and sanitation impacts women and girls disproportionately heavily. Continuous piped water at the household level has great health benefits and reduces the burden of unpaid care and domestic work that falls on women and girls. Also critical for gender equality are safely managed sanitation facilities, not only in private households, but also in public spaces: schools, transportation hubs, publicly accessible government offices, health clinics, markets, and workplaces. As such, countries should take affirmative action to alleviate gender-based burdens and discriminations, design policies and projects that include a gender lens, and partner with women rights organizations. Gender roles that may be embedded in local environments should also be addressed by promoting adequate and effective workshops.

Design sustainable and climate-friendly water and sanitation systems.

Deficiencies in wastewater management or solid waste disposal have detrimental effects on the environment. However, solutions to these issues can also have adverse environmental effects if sustainability aspects are not taken into account. It is therefore essential to consider sustainability and climate resilience when designing water and sanitation policies and projects. As global warming increasingly poses substantial challenges to the provision of drinking water, especially in developing countries, long-term considerations cognizant of climate change and seek to bolster resilience to it should be incorporated in government action.

Introduce and overhaul data infrastructure in water and sanitation.

Most countries, but especially developing countries, often struggle due to insufficient and unreliable data undermining decision-making within the sector. Where this is the case, it is critical that countries transform existing data governance structures to ensure a more systemic, human-centric, and multi-stakeholder collaborative system to support more comprehensive water resources assessment in planning and decision-making processes.[56] Frontier technologies such as big data, cloud-based solutions, satellite, and Internet of Things, present opportunities for reliable data collection and thus better decision-making in water and sanitation management, supporting a more comprehensive water resources assessment, improving decision-making, and minimising water losses and waste.

Scale up good practices for universal access to water and sanitation and IWRM with proven track records.

Governments should assess what factors hinder or accelerate local and national scale-ups of good practices and should seek to address or promote them appropriately by supporting them fiscally and non-fiscally. Local actors should be encouraged to participate in international networks of cooperation where they can learn from successful actors from other countries. Circular economy and nexus approaches to water and sanitation should be explored, considering how synergies between sectors can increase impact and turning treated wastewater into a water resource where appropriate.

[56] Contributions from the Governments of the Dominican Republic, Latvia, and the Philippines

Introduce new, innovative, and more equitable financing mechanisms.

Financial innovation is critical to ensuring water security. Blended financing models at the macro-level combined with micro-financing for small scale operators are imperative for the creation of an enabling environment for sustainable water businesses. Micro-financing has also proven effective as a means to provide grants for households to address WASH issues specifically. Governments should take advantage of opportunities provided by sustainable and green finance as well as innovative finance solutions such as PaYGo. Increasing donors' attention to water and sanitation specifically can also help draw financial resources into the sector. There are competing needs within a country when listing items for cooperation with donors. Given the essential role that water and sanitation plays in the economic, social and environmental spheres of a country, a strong degree of priority should be given to them.

The international community, meanwhile, should consider the following:

Technology transfer and upgrading.

The international community should promote technology transfer between developed and developing countries in managing water and sanitation. Such transfers must represent complete packages including the building of local capacity and capability to operate, maintenance, and, where needed, information as to how such technology ought to be adapted for the relevant local context. Furthermore, developed international community should support the upgrading of water and sanitation infrastructure and the development of appropriate water management in developing countries, through technology transfer, financial support, and the sharing of expertise. This might for instance involve benchmarking and sharing best practices and technologies through North-South or South-South cooperation.

Promote knowledge and experience transfers.

Humanity already possess extensive knowledge and experience which can contribute massively to addressing the challenges in meeting SDG 6. Multilateral organizations, development agencies, and global networks of water and sanitation actors should actively work to direct and increase the global flow of water and sanitation STI knowledge from production centres to all member states through knowledge portals and exchanges, online learning platforms, practitioner networks, and smart dissemination mechanisms. The sharing of STI practices will also help forge new local and international collaborations, strengthening innovation ecosystems worldwide. In addition to each organization's own platform, the CSTD, as the focal point in the UN system on science, technology and innovation for development, provides a central platform to share knowledge, build consensus and synergies between organization-wide initiatives.

Provide capacity building for water and sanitation actors in developing countries.

Training and capacity building are a crucial complement to knowledge and technology transfer. Capacity building efforts must be carried out in tandem with these transfers in order to ensure the long-term functioning of water and sanitation solutions and the effective application of transferred knowledge. During these processes, regard of the local context should be taken into consideration.

Promote North-South, South-South, and triangular cooperation on STI.

Foster international partnership for SDGs involving multiple actors and networks with global, regional, and sub-regional focuses to ensure future sustainability of our planet's water resources.[57]

Improve data on gender and WASH.

To effectively monitor SDG progress, the international community must cooperate to build awareness and technical capabilities to measure gender-specific indicators and disaggregate WASH data. Indicator 6.1.1 which monitors progress towards target 6.1 on safe drinking water for all is not disaggregated by gender. Conversely, target 6.2 explicitly recognizes that women and girls have specific sanitation and hygiene needs. However, indicator 6.2.1 does not currently track whether efforts to expand access to safely managed sanitation respond to those needs by disaggregating by gender. If progress towards safe water and sanitation is to be monitored for all, improved gender-disaggregated data and gender statistics are needed.

Strengthen international networks and provide financing for developing countries, especially countries in special situations (LDCs, LLDCs, and SIDS).

The international community must be supportive of stakeholders' participation in international networks and programmes to build their capacity in addressing challenges in ensuring safe water and sanitation. These WASH-specific networks are best placed to pool and provide financing to countries in need, to expand their national capacities, and to identify and develop relevant technologies in an effort to ensure safe water and sanitation to the whole global population.

Prepare the global water and sanitation community for the effects of climate change

through cooperation and a global focus on building climate resilient water and sanitation systems. Ensure shared knowledge and STI solutions have built-in climate resilience. Promote cross-sectoral coordination across the water-energy-agriculture nexus to address and exploit their interlinkages.

[57] Contribution from the Government of Thailand

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Annex: Examples of STI initiatives and solutions from input contributors

SDG 6 generally	
R&D and technological development promotion India	India's Water Technology Initiative (WTI) fosters and promotes R&D activities and technology development to achieve SDG 6 by establishing virtual research and innovation centres as focal points to bring stakeholders and experts together and nurture knowledge.
Technology evaluation and incubation South Africa UNU	South Africa's Water Technologies Demonstration Programme (WADER) promotes the early adoption of promising technologies and accelerates innovation in the water sector by showcasing technologies that have gone through a credible assessment process.
	The Frugal Innovation and Entrepreneurship in Water 4.0 in Africa (FIUWA) project identifies stakeholders to coordinate and organize them into a water sector innovation ecosystem. It is examining how frontier technologies help provide enterprise-driven solutions.
Innovation competitions UNWTO	The UNWTO Startup Competitions and Innovation Challenges Programmes reward winning projects with publicity, a curated programme of benefits, giving them access to mentorship opportunities and technological support, and connection to Member States, corporates, and investors. One of its categories is SDG 6.
6.1 Universal and equitable access to safe and affordable drinking water.	
Automatic water quality monitoring China	Innovations for online and real-time water quality monitoring. Data collection methods include satellite remote sensing, 'meter-level' information products, and other sensor systems used to detect risk sources (heavy metals, VOC, etc.) in water source regions.
Rainwater collecting cellars and water saving appliances China	China's Water Cellars for Mothers project addresses water shortages through the construction of rainwater collecting cellars. Simultaneously, the China Women's Development Fund has helped drastically cut average water collection times in pilot villages.
5G high-resolution precipitation monitoring Hungary	Hungary is developing a water quality tracing system covering its drinking water supply network, hydrodynamic models to control biological wastewater treatment (WWT) processes.
Desalination technology India	India's Mission on Desalination (NMD) identifies recognized and promising desalination technologies and works with international and local partners to make widespread desalination sustainable and workable to provide water security and clean and safe drinking water.
Renewable energy use to reduce the cost of water Latvia	Latvia has installed renewable energy resources to produce electricity for water supply enterprises' consumption. By reducing their electricity expenses, tariffs for drinking water are reduced and consumer interest in using the centralized water supply is increased.
Household / community-based water filters Philippines; UNIDO	At the Industrial Technology Development Institute of the Philippines Department of Science and Technology, nanotechnology has been used to develop ceramic water filters with anti-microbial nanocoating and household /community-based filters to remove harmful metals from water. Both technologies have been field-tested in communities where there is a need for potable drinking water. Similarly, a filtering drinking straw, the "Mabuhay Straw", has been developed using additive manufacturing and 3D printing.

Installation of decentralized technologies to increase access to water Philippines UNU	The Filipino Department of Science and Technology (DOST) Region IVB has implemented 15 projects providing multiple technological solutions to improve access to clean water. To ensure that these water technologies are optimized to provide the best water service while saving utility costs, the agency equipped them with solar power systems. These STI water technologies have benefitted 2,081 households or at least 10,400 persons from diverse sectors such as women and the indigenous peoples. Identifying which technological solution is best suited to which context, as was done here, is key to effective mobilizations of STI for water and sanitation.
	The Agrophotovoltaics for Mali and The Gambia (APV-MaGa) and RETO-DOSSO projects are both exploring the potential for solar systems to improve access to water not only for drinking but also for agricultural purposes and thus food security. UNU has explored how efficiency and sustainability in water usage can be maximized via intelligent systems incorporating smart sensors, microcontrollers, and the Internet of Things. Real-time data access will aid the monitoring of weather, water demand and water allocation.
6.2 Adequate and equitable sanitation and hygiene for all and end to open defecation.	
Capacity building through training and exchange Dominican Republic; Mexico	The Mexican Institute of Water Technology (IMTA) and the Dominican Republic's National Institute of Potable Water and Sewage (INAPA) cooperated to exchange, transfer and strengthen capacities in social technology, participatory strategies and governance, to protect the human right to water and sanitation in rural and marginalized communities. INAPA promoters and staff were trained in the adoption of alternative technologies for the collection, treatment, supply, consumption, and disposal of water.
Support for emerging innovative sanitation technologies South Africa WHO	The South African Sanitation Technology Enterprise Programme (SASTEP) innovation platform has been established to fast-track the adoption of innovative and emerging sanitation technologies in South Africa through by fostering local manufacturing and commercialization.
	In Madagascar and Ethiopia, a new methodology has been developed with the European Union's Joint Research Centre that uses both satellite remote sensing to scan and identify high potential sites for the extraction of groundwater and on-the-ground geophysics investigations has substantially improved drilling success rates. For instance, remote sensing helped increase drilling success rates from less than 50% to over 90% in Ethiopia.
Decentralized wastewater treatment systems UNEP	In collaboration with the Bremen Overseas Research and Development Associate (BORDA), UNEP has developed and disseminated the Guidelines for Application of Small-Scale, Decentralized Wastewater Treatment Systems.
Decentralized solar powered water and sanitation systems UNIDO	In Madagascar, UNIDO is collaborating with the One WASH national program to improve public health through the provision of solar powered water and sanitation systems. It is also helping distribute and implement them in Ethiopia.
Ultrasound technology Dominican Republic	The Santo Domingo Aqueduct and Sewer Corporation (CAASD) employs ultrasound technology to prevent algae blooms in sources of drinking water.
Wastewater biofuel Egypt	The "Haya Karima Initiative" aims to produce biofuel using sludge from wastewater treatment plants
Online monitoring systems Egypt	Egypt aims to introduce an online monitoring system for wastewater discharge from major polluting enterprises in order to determine wastewater pollution loads and take necessary responsive action.

6.4 Increase water use efficiency across sectors and reduce the number of people suffering from water scarcity.	
Geoelectrics **Austria** **Belize**	Geosphere Austria will develop and use geoelectrics, which involves the measurement of the electrical resistance of the subsoil, to determine subsoil water content and thus better understand the health and availability of groundwater resources. Belize has also procured an electrical resistivity meter to help locate groundwater resources.
Solar pumping **Dominican Republic; Cuba; Germany**	The Cuba – Germany – Dominican Republic Triangular Project aims to strengthen Dominican institutions' knowledge on green recovery and increasing their technological capacities. Three training workshops on solar pumping photovoltaic solutions have been held and the execution of three pilot projects is planned.
AI/IoT-based forecasting and modelling **Japan**	As part of its Partnership for Quality Infrastructure foreign infrastructure investment initiative focused on Asia, Japan is integrating AI/IoT-based precipitation and flood analysis, disaster risk assessment, and management of the hydropower, sewage system, water supply, sanitation, and agricultural infrastructure projects that it is the driving force behind.
Automated hydrometric stations **Peru**	In Peru, automated hydrometric stations have been installed to allow for the surveillance of water quality and quantity using sensors and through remote detection of water quality through spatial and terrestrial gatherings of multispectral and hyperspectral data. With its Water Observatory, it has created an interactive digital platform to provides the official and updated data it collects on the quality and quantity of surface water.
AI/ML to curb urban water shortages **Philippines**	The Filipino DOST has initiated the Collaborative Research and Development to Leverage Philippine Economy (CRADLE) Program seeking to harness the power of artificial intelligence (AI) and machine learning (ML) to help curb water shortages in the east service area of Metro Manila.
Satellite-based water pipe leakage detection **IDB**	In Argentina, AySA applied a non-intrusive satellite method developed to identify and control water losses. In the pilot area where it was applied over 5,000 km of pipes, 1,105 points with high potential for leaks have been detected, generating savings of 2,000,000 m3 per year and increasing leak detection efficiency by 138%.
Use of predictive AI and geographic data for water infrastructure planning **IDB**	In Ecuador, EPMAPS' AguaQuitoPeriférica project employs geographic artificial intelligence techniques, presented in an environment based on geographic information systems (GIS) at the neighbourhood level to model possible future scenarios to be considered for planning the demand for the service. In its current phase (2022), it is starting to use data from space-based platforms including NASA and Google Earth Engine.
6.5 Implementation of integrated water resource management at all levels.	
Rural Water and Sanitation Information System (SIASAR) **Honduras, Nicaragua, Panama, Dominican Republic, Costa Rica, Oaxaca (Mexico), Peru, Bolivia, Colombia, Paraguay; World Bank**	SIASAR is a joint initiative between governments. Its strategic objective is to have a basic, up-to-date and verified information tool on the existing rural water supply and sanitation services in a country. It aims to support planning, coordination and evaluation by stakeholders, allow for monitoring, to record and evaluate the performance of stakeholders, and to allow data transfer with other databases. It is designed to be applied in other countries with similar rural water and sanitation systems (low levels of coverage, limited self-sustainability, little information, etc.).
Online cadastral data **Dominican Republic**	The Santiago Aqueduct and Sewerage Corporation (CORAASAN) uses Geographic Information System (GIS) to geolocate, store and analyze its cadastral data, storing, organizing and using the data to create a model the entire distribution network.
Satellite data sharing **Japan**	To help fill observation data gaps, Japan shares data collected by its meteorological satellites including "Himawari" and its Advanced Land Observing Satellite-2 (ALOS-2) "Daichi-2" with other countries in the Asia-Pacific region through the Group on Earth Observation (GEO).

Drone imagery **Peru** **Belize** **Dominican Republic** **Gambia**	Belize has used drones to capture aerial imagery of flooding events to better understand them. Equally, the have been utilized to determine the best locations for the placement of monitoring stations. The Dominican Republic's National Institute of Potable Water and Sewage (INAPA) uses drones for data management, information exchange and decision making for the design, redesign, treatment, and maintenance of drinking water and sanitation systems. Gambia has started using drones and early warning systems to address preand post-flood disaster through long-term climate risk assessments. Drone data helps to address outdated topographic data. The program's objective is to alleviate poverty by reducing flood risk and increasing food disaster resilience. Peru has used drone technology to delimit 'marginal areas' of water bodies and identify vulnerable sites.
Mobile monitoring technologies for flood modelling **Latvia**	A Latvian project uses mobile pipe flushing device that collects data on water flow, pressure, and turbidity to create tailored 3D river flood models. This water monitoring solution can predict flood threats 24 hours ahead of time.
Watershed monitoring using satellite imagery and AI **Philippines**	DOST-ASTI through its Remote Sensing and Data Science (DATOS) Project has developed a GIS plugin to train and implement AI models in extracting features from satellite imagery. The technology uses the agency's High-Performance Computing which can be used by public users from academic institutions as well as government agencies.
Reservoir water management using scientific and technological solutions **Russia**	The Russian government has implemented Schemes of Comprehensive Use and Protection of Water Objects (SCUWO) by using employing scientific and technological water management solutions. The project constitutes the basis of the water management of reservoirs located within the boundaries of river basins. SCUWOs are developed to assess the admissible anthropogenic load on water objects; to identify the needs for water resources in the future; to ensure the protection of water resources; and to specify the main areas of activity to prevent the negative impact on water reservoirs
Creation of a Sustainable Development Performance Indicator (SDPI) enabling low-cost and scalable sustainable water allocation **UNRISD**	UNRISD has funded and initiated the development of a context sensitive Sustainable Development Performance Indicator (SDPI) for sustainable use of water at the facility level. It establishes a low-cost and scalable method for providing a sustainable water allocation for enterprises based on the hydrological, economic, and demographic contexts of their facilities. When compared to enterprises' actual water withdrawals, the allocation calculated according to the model provides an indication of the sustainability of their economic activity with respect to water. The SDPI relies on relatively straightforwardly determinable data inputs: location (latitude and longitude), Gross Water withdrawals, non-consumptive use (i.e. wastewater discharge), Gross Revenue of facility (USD$ per year), and number of full-time equivalent employees of the facility). This means the indicator can easily be upscaled and widely disseminated among enterprises, perhaps by governments, in the form of a digital tool.
Financial tracking of WASH funds **WHO**	WHO has developed the TrackFin methodology to identify and track financial flows in the WASH sector. Collecting and mapping WASH financial flows in a comprehensive and comparable manner through standard TrackFin classifications allows for national benchmarking, cross-country comparisons, and the establishment of an evidence base to better plan, finance, manage and monitor WASH services and systems.

Online hydrology simulation and resource management tool **IDB**	HydroBID is an integrated quantitative online system to simulate hydrology and water resources management that uses a combination of smart metering and the Internet of Things (IoT) to foster sustainability, to evaluate the quantity and quality of water, inform infrastructure needs, and the design of strategies and adaptive projects in response to these changes.
ML-supported Earth Observation analysis of informal settlement populations and dynamic modelling of hydrologic data **UNU**	The AquaMount project aims to improve water management and prevent water scarcity in South Africa/Lesotho by (traditionally) investigating where governance and planning is problematic but also through machine-learning supported Earth Observation analysis to estimate the population density of informal settlements, and through the analysis of climate and hydrologic data using dynamic modelling and other methods to understand the historical conditions of water availability.
Water technician training enhanced by innovative training tools **UNIDO (& partners)**	Combining hands-on experience and cutting-edge technology, a program called H2O Maghreb has been developed to equip the next generation of Moroccan water technicians with the skills necessary for ensuring sustainable water use. Innovative training tools including Virtual Reality (VR), Environmental Discovery Systems (EDS) and the IEA training platforms have been used and the project is linked to UNIDO's global knowledge sharing platform, the Learning and Knowledge Development Facility (LKDF). It is planned to replicate this project in Madagascar.
6.6 Protect and restore the health of water-related ecosystems.	
Mesocosm research and monitoring **EU; Türkiye**	AQUACOSM-plus, founded in 2020 with a planned to finish in 2024, is helping drive European mesocosm-based aquatic research by integrating leading mesocosm infrastructures into a coherent, interdisciplinary, and interoperable network covering all ecoregions of Europe.
Wastewater management using ISTP treatment technology in water-based settlements **UNEP**	ACT Malaysia and UNEP have collaborated to build wastewater management capacity. After testing the feasibility of ISTP wastewater treatment technologies, 10 tanks have been installed with ten residents trained in their installation and maintenance. Phase Two of the project involves empowering local communities (with a focus on women) to stop wastewater pollution into their natural environment. By reducing wastewater pollution, better quality water can sustain marine-related economies. Ultimately, the project is expected to contribute to the development of policies for the long-term conservation of coastal water quality as well as for tackling wastewater pollution.
Nutrient recovery from wastewater **UNEP**	A UNEP project is seeking to put in place a system for the recovery of nutrients from wastewater in Delhi, India. The project assesses the best treatment technology for such purpose and aims to develop an ecosystems health report card (EHCR) for three lakes in the area.
Regional cooperation to address transboundary environmental stresses: The Mediterranean Sea Programme **UNEP**	UNEP/MAP implements the Mediterranean Sea Programme: Enhancing Environmental Security (MedProgramme) which aims to reduce the major transboundary environmental stresses affecting the Mediterranean Sea and its coastal areas, while strengthening climate resilience and water security and improving the health and livelihoods of coastal populations. MedProgramme is structured around four components: Reduction of Land Based Pollution in Priority Coastal Hotspots and measuring progress to impacts; Enhancing Sustainability and Climate Resilience in the Coastal Zone; Protecting Marine Biodiversity; and Knowledge Management and Programme Coordination. Implementation of the project is underway in 10 beneficiary countries sharing the Mediterranean Sea.

Near Real-Time Monitoring System for Marine Coastal Eutrophication Using the Google Earth Engine **UNEP (& partners)**	This two-year project will produce an interactive map of potential eutrophication area over the global ocean to help Northwest Pacific Action Plan (NOWPAP) Member States and countries around the world to manage eutrophication and report their progress under the 2030 UN Sustainable Development Agenda.
Freshwater Ecosystems Explorer **UNEP**	UNEP's Freshwater Ecosystems Explorer data platform leverages the best available science and data to track, monitor and improve the health of freshwater ecosystems, globally, for SDG 6.6.1.
6.a International cooperation and capacity building in developing countries through waste water treatment, desalination, recycling and reuse technologies etc.	
Low-cost desalination and water purification kiosks **Switzerland**	Swiss Fresh Water (SFW) has developed a small low-cost desalination system for salt or brackish water using an ultra-filtration, carbon filtering and reverse osmosis filtration system which can be powered by solar or grid energy. It allows for the small-scale production of drinking water (4'000 liters drinking water / day) which sold at a price 3 to 10 times cheaper than bottled water. The is easy to use and maintain, has low energy consumption, alongside sensorand IoT-based remote monitoring, making it suitable for use in developing countries, notably in Africa. A pilot project started in 2012 in the Sine Saloum Delta in Senegal, home to 225,000 people suffering from brackish and fluorinated water has proven to be successful from 2012 to 2019. In addition, SFW has set up more than 120 water kiosks on a franchise model in urban and peri-urban areas, around which small craft and service development centres have developed, generating more than 500 jobs through this income generating activity. Following its success in Senegal, SFW is now beginning plans to replicate the model in West Africa, South America, and Asia through partners including REPIC.
MOOC on Sanitation, Water and Solid Waste for Development **WHO**	WHO has contributed to four Massive Open Online Courses (MOOCs) developed by Eawag (the Swiss Federal Institute of Aquatic Science and Technology) on "Sanitation, Water and Solid Waste for Development". The courses reached over 160,000 learners and were completed by over 25,000 people, with high participation from low and middle-income countries.
The World Summit on the Information Society **ITU**	The World Summit on the Information Society (WSIS) Forum and other WSIS-related processes and activities have been providing a platform to share knowledge and information, promote best practices in all segments of life, including matters of sanitation and safe water. Co-organized by ITU, UNESCO, UNDP, and UNCTAD, the WSIS Forum has created a meaningful matrix linking WSIS Action Lines with SDGs. As regards SDG Goal 6, WSIS Action Lines on access to information, capacity building, ICT applications e-Science, and cultural diversity and local context have been highlighted. The WSIS, in seeking to help share and encourage ICT policies, strategies, laws, programmes and initiatives that promote cleaner and more efficient production, enables solutions that address issues relating to water and sanitation.

6.b Participation of local communities for improvement of water and sanitation.	
Capacity building for sustainable entrepreneurship among women and youth **UNU**	The Youth and Women Green Entrepreneurship in Africa (YW-GSE) project seeks to mobilise stakeholders and provide capacity-building, facilities and funds to promote green entrepreneurship (water management falling within that) among key population groups through a virtual learning space, a Pan African virtual incubator and accelerator, and networking, mentoring and other resources provided online.
Community-managed solar pumping facilities **UN Women**	The Solar Water Pumping for Drinking and Irrigation in the village of Ndombe (Mozambique) has a photovoltaic solar water pumping system that is managed by the community, including many women. The enhanced irrigation system allows women to sell vegetables and fruits and increase their income, while the better yield also improved diets and reducing malnutrition.

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