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Ensuring safe water and sanitation for all: a solution through science, technology and innovation

Report of the Secretary-General

Summary

This report examines the role and potential of science, technology and innovation as key enablers of catalytic change in the global achievement of Sustainable Development Goal 6 on ensuring availability and sustainable management of water and sanitation for all. The report highlights the deep-rooted relationship between the two and analyses how science, technology and innovation can contribute significantly to overcoming the persistent challenges to achieving Goal 6, with a focus on the distribution and delivery of safe water and sanitation, integrated water resources management and the addressing of inequalities in the sector, notably in relation to gender. The report also highlights the potential of frontier technologies.

The report concludes with suggestions for member States and the international community, including the consideration of science, technology and innovation as part of careful, context-specific policies to bring solutions to fruition. The suggestions include embracing decentralized solutions and considering the nexuses of water and other sectors. The international community can greatly assist countries in achieving Goal 6, notably by pooling knowledge and technological know-how through sharing mechanisms and by developing innovative financial mechanisms to support water and sanitation-related projects in developing countries.

Introduction

1. At its twenty-fifth session, in April 2022, the Commission on Science and Technology for Development selected “Ensuring safe water and sanitation for all: A solution through science, technology and innovation” as one of its priority themes for the 2022–2023 intersessional period.

2. The secretariat of the Commission convened an intersessional panel on 25 and 26 October 2022 to contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-sixth session. This report is based on the issues paper prepared by the secretariat, the findings of the panel, country case studies contributed by Commission members, relevant literature and other sources.[1]

3. Access to water and sanitation is a basic human right. Substantial progress has been made in achieving Goal 6, but there is cause for concern and a need for solutions that accelerate progress and ensure no one is left behind. Certain factors, including better policies and governance, more funding, improved infrastructure and improved data for better decision-making, are central to implementing solutions. In addition, science, technology and innovation can have a particularly significant role. Countries are now more attentive to the development and deployment of new technologies and processes, and new applications have the potential to increase the efficiency and effectiveness of existing water and sanitation systems, to secure water and sanitation for all.

I. Persistent challenges in ensuring safe water and sanitation for all

4. Safe water and sanitation, as framed under Goal 6, is a key component of the global development agenda. Due to the crucial role of water and sanitation in virtually all aspects of life, every other Sustainable Development Goal relies in some way on the achievement of Goal 6. Examples include the criticality of water and sanitation in the achievement of good health and well-being, gender equality and the empowerment of women and girls, food security and sustainable and accessible energy, as well as in ending poverty. A review of the global status of progress towards meeting the targets indicates that the world is not on track to achieve Goal 6 and that many countries are moving backwards. Progress towards all targets is slow, yet there are two areas of particular concern.

5. First, progress towards universal access to safely managed drinking water and sanitation services (figure 1). In 2020, although the figure had decreased significantly, 2 billion people still lacked access to safe water.[2] By 2020, more limited progress had been achieved in enhancing access to safe sanitation, with access for 2.4 billion people. If current trends persist, by 2030, only 81 per cent of the global population will have access to safely managed water and 67 per cent, to sanitation services.[3] Achieving the related targets by 2030 requires a fourfold increase in the current rate of progress.

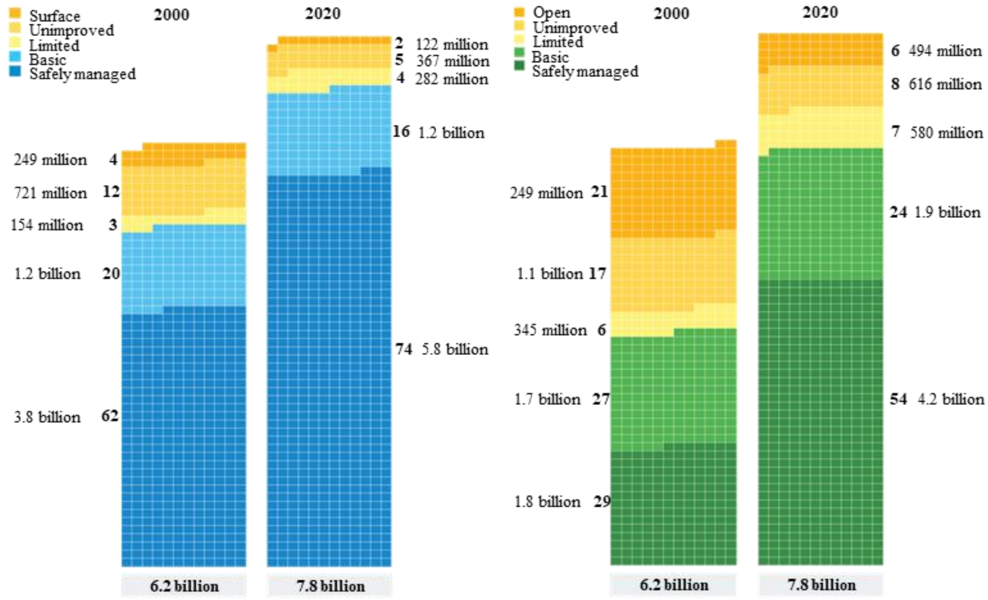
[1] Contributions from the Governments of Austria, Belarus, Belize, Brazil, Cameroon, China, Cuba, the Dominican Republic, Ecuador, Egypt, the Gambia, Hungary, India, Japan, Kenya, Latvia, Oman, Peru, the Philippines, Romania, the Russian Federation, South Africa, Switzerland, Thailand and Türkiye, as well as the Inter-American Development Bank (IADB), the International Telecommunication Union (ITU), the International Water Management Institute, the United Nations Entity for Gender Equality and the Empowerment of Women (UN-Women), the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), the United Nations Research Institute for Social Development (UNRISD), the United Nations University Institute for Environment and Human Security, the World Health Organization (WHO) and the World Tourism Organization are gratefully acknowledged. For all documentation from the intersessional panel, see https://unctad.org/meeting/cstd-2022-2023-inter-sessional-panel. *Note*: All websites referred to in this report were accessed on 3 January 2023.

[2] See https://www.unwater.org/publications/summary-progress-update-2021-sdg-6-water-and-sanitation-all.

[3] WHO and United Nations Children’s Fund, 2021, *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020: Five Years Into the Sustainable Development Goals*, Geneva.

Figure 1
Trends in access to water and sanitation services: Share of global population
(Number of people and percentage)

(a) **Global drinking water coverage** (b) **Global sanitation coverage**



Source: WHO and United Nations Children's Fund, 2021.

6. Second, the implementation of integrated water resources management, which is crucial in ensuring water-related sustainability. Globally, the rate of integrated water resources management implementation needs to double, as 87 countries continue to report low or medium–low levels of implementation.[4]

7. Closer examination reveals inequalities in four different areas. First, there is a broad disparity between regions, with sub-Saharan Africa furthest behind; the region has a 30 per cent level of coverage of safe water services and 21 per cent, of safe sanitation services. Coverage of safe water services is at 96 per cent in Europe and Northern America and 78 per cent in Australia and New Zealand.

8. Second, there is a disparity between countries. The least developed countries are furthest behind and different countries in the same regions differ significantly. In 2020, nearly half of the population without access to basic drinking water lived in the least developed countries and most of the population in Europe and North America generally had contaminant-free water available. In Eastern and South-Eastern Asia, coverage of safe drinking water services was at 94 per cent in Malaysia; in Cambodia and the Lao People's Democratic Republic, coverage was at 28 and 18 per cent, respectively. In Latin America, coverage was at 43 per cent in Mexico; in Chile and Ecuador, coverage was at 99 and 67 per cent, respectively.[5] The least developed countries, landlocked developing countries, small island developing States and countries in Central and Southern Asia and sub-Saharan Africa have a greater share of the population using on-site (non-sewer) sanitation facilities.

9. Third, there is a disparity within countries, particularly regarding urban and rural coverage, with rural populations having significantly lower levels of access to safe water and sanitation compared with urban counterparts. Globally, in 2020, 86 per cent of the urban population had access to safe water services, compared with 60 per cent of rural inhabitants.[6] Urban populations also have better quality services, with two thirds having

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[4] UNEP, 2021, *Progress on Integrated Water Resources Management: Global Indicator 6.5.1 Updates and Acceleration Needs*, Nairobi.
[5] WHO and United Nations Children's Fund, 2021; Contribution from the Government of Ecuador.
[6] WHO and United Nations Children's Fund, 2021.

sewer connections compared with one in seven people in rural areas, where on-site sanitation facilities predominate. For example, in Romania, which is among the lowest ranking countries in the European Union, with a rate of connection to water services at 72.4 per cent and to sewerage services at 57.4 per cent, the differences between urban and rural areas are significant, with smaller communities in rural areas lagging considerably.[7]

10. Finally, vulnerable, marginalized and disadvantaged groups, including women and people with disabilities, face additional barriers to accessibility, availability and the quality of services.[8] Women and girls are disproportionately affected by water and sanitation access challenges. Long journeys to obtain water or the need to use water and sanitation facilities that are not on premises not only takes time but may also expose them to physical and sexual violence.[9] People with disabilities face more challenges in accessing water and sanitation. In developing countries, most public toilets are not accessible to users of wheelchairs, and in developed countries, 69 per cent of public toilets remain inaccessible.[10]

11. Climate change poses an increasingly significant challenge to the achievement of Goal 6, given its influence on the water system of the Earth. Impacts on freshwater stocks and availability and on water safety and quality will be particularly pronounced as extreme weather events, in particular droughts and floods, become widespread and more common. For example, in Cameroon, there has been an atypical recurrence of extreme weather events, including violent winds, high temperatures and long periods of drought or heavy rainfall that endanger human communities and ecosystems.[11]

II. Applications of science, technology and innovation in water and sanitation

12. Solutions are urgently needed to speed up progress on achieving Goal 6, and science, technology and innovation are critical means in the development and delivery of such solutions. Contributions are made in the following three interlinked realms: analytical science that focuses on research and knowledge augmentation; solutions through technological invention and innovations that attend to problems; and implementation through the embedding and upscaling of such solutions. Recognition of the wide spectrum of innovation is crucial. The general assumption is that innovation is primarily technological, yet while technological innovation is an invaluable contributor to achieving Goal 6, it is insufficient on its own. Achieving a real and lasting impact requires a wider spectrum of innovation, namely, in operational processes (process innovation), in policy and governance to enable new solutions to be introduced more rapidly and sustainably (policy innovation) and in a social focus and outcomes that recognize that water management should be people-centred and must operate in particular social and cultural environments (social innovation).

13. Analytical science is a crucial component of the knowledge required to address water and sanitation-related challenges and is the bedrock of solution development. There is a large repository of information and knowledge in journal articles and reports, yet knowledge production is concentrated in a few countries, with almost 50 per cent of global publications produced in China, India, the Russian Federation, the United Kingdom of Great Britain and Northern Ireland and the United States of America (figure 2). The

[7] Contribution from the Government of Romania.

[8] See https://www.unwater.org/publications/eliminating-discrimination-and-inequalities-access-water-and-sanitation.

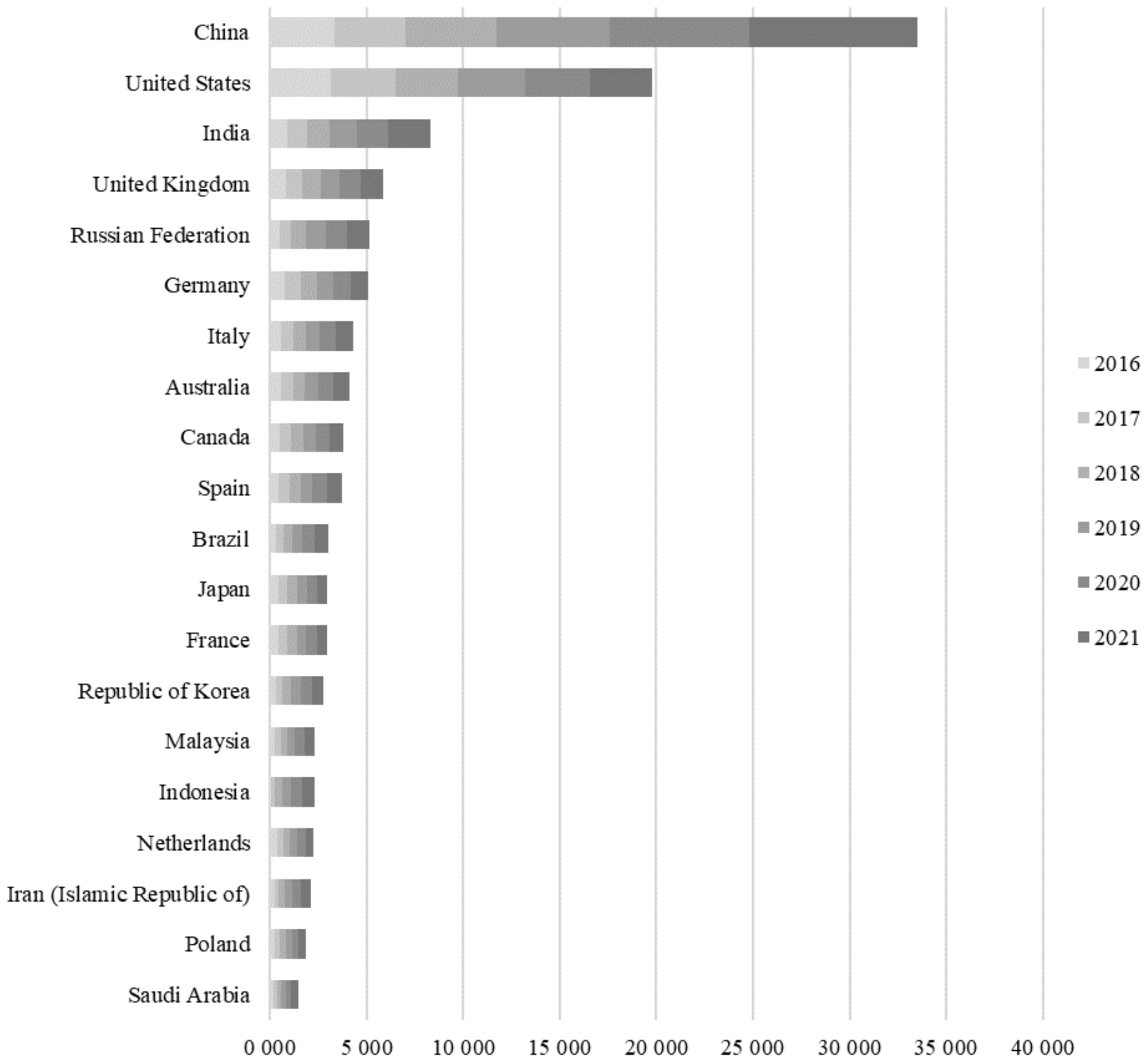
[9] GM Assefa, S Sherif, J Sluijs, M Kuijpers, T Chaka, A Solomon, Y Hailu and MD Muluneh, 2021, Gender equality and social inclusion in relation to water, sanitation and hygiene in the Oromia region of Ethiopia, *International Journal of Environmental Research and Public Health*, 18(8); N Scherer, I Mactaggart, C Huggett, P Pheng, M Rahman, A Biran and J Wilbur, 2021, The inclusion of rights of people with disabilities and women and girls in water, sanitation and hygiene policy documents and programmes of Bangladesh and Cambodia: Content analysis using Equi Frame, *International Journal of Environmental Research and Public Health*, 18(10).

[10] See https://www.un.org/development/desa/disabilities/publication-disability-sdgs.html.

[11] Contribution from the Government of Cameroon.

majority of developing countries face major challenges in achieving Goal 6 and are neither significant producers nor consumers of related knowledge; a major factor in this regard is limited institutional and individual capacity to monitor and access new knowledge and knowledge products. There is a pressing need, therefore, to strengthen knowledge-sharing with developing countries.

Figure 2
Leading 20 countries by number of science, technology and innovation and water-related publications



Source: UNCTAD secretariat calculations, based on data from Scopus.

14. With the rapid production of new knowledge that is responsive to people's water and sanitation needs, technological and innovative solutions in these sectors have made great strides in recent years. Multiple technologies and innovative practices are helping to address challenges in each part of the water and sanitation value chain. The key is to expand and scale up the application of proven solutions where needed and appropriate. Innovative financing mechanisms, through blended finance or public–private partnerships, are not only important in the nurturing and development of technological and innovative solutions, but also in their implementation in developing countries.

A. Safe water and sanitation

15. Access to safe water and sanitation is a challenge across developing countries, but different countries and areas within countries have particular priorities. In some, there is a need to increase water-related infrastructure or find water resources, due to water stress, and in others, there may be water resources available but there are challenges related to obsolete infrastructure assets, excessive levels of water consumption or pollution and contamination issues. Access to sanitation presents a more uniform picture and is significantly less context-dependent, requiring above all the establishment of proper sanitation facilities. This can be costly and the best way of doing so, particularly with regard to dealing with waste, varies depending on the context. Multiple currently available technologies and innovative practices can help address water and sanitation-related challenges.

1. Clean water accessibility

16. Cities and towns in developing countries generally have safe running potable water due to centralized water treatment plants that purify water to a potable standard. Worldwide, however, peri-urban slums and communities in rural areas do not have access, with an estimated 2 billion people lacking access to safely managed drinking water at home.[12] In addition, significant progress has been made in improving water treatment through the use of nanotechnology, ceramic filters and smart process design, as well as greater energy and chemical use efficiencies, yet in many parts of the world, access to such technological and innovative solutions is lacking. With an estimated 80 per cent of wastewater currently returning to freshwater sources untreated, risks of waterborne diseases and harm due to chemical and other contaminants are greatly increased.[13]

17. Several actors are making efforts to provide technological and innovative solutions, for the simple, low-cost and decentralized abstraction and production of clean water for underserved populations. Many involve a simple filtration or desalination or similar system. For example, in Kenya, Give Power uses systems that convert salt or brackish water into clean drinking water through advanced filtration and solar-powered desalination technology, mainly in Kiunga, a fishing community of around 3,500 people in an extremely dry region.[14] In South Africa, point-of-use systems employ a combination of flocculation, coagulation, filtration and distillation to deliver safe and clean water for consumption and other uses.[15] Swiss Fresh Water distributes small, low-cost desalination systems for salt or brackish water using sensor- and Internet of things-based remote monitoring; in 2012–2019, it provided clean water to 225,000 people in Senegal at a price 3–10 times cheaper than bottled mineral water.[16]

18. Innovative water delivery systems that do not involve high levels of technology can be effective in providing water to disadvantaged populations, for example in slums, in which around one quarter of the global urban population live and where access to water and sanitation is a major challenge.[17] For example, in Kenya, in what is considered the largest slum in East Africa, one non-governmental organization has developed an innovative water delivery system using an aerial pipeline and distribution through a network of water kiosks, an approach that circumnavigates the complicated and costly logistical barrier of laying water pipes across a densely populated unplanned settlement; the system has benefited an estimated 250,000 people within a peri-urban area of 2.5 km^2.[18]

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[12] See https://www.cdc.gov/healthywater/global/wash_statistics.html.

[13] See https://www.unep.org/explore-topics/water/what-we-do/tackling-global-water-pollution.

[14] Contribution from the Government of Kenya.

[15] CK Pooi and HY Ng, 2018, Review of low-cost point-of-use water treatment systems for developing communities, *Nature Partner Journals Clean Water*, 1.

[16] Contribution from the Government of Switzerland.

[17] See https://www.habitatforhumanity.org.uk/blog/2017/12/the-worlds-largest-slums-dharavi-kibera-khayelitsha-neza/.

[18] See https://www.theguardian.com/global-development-professionals-network/2016/oct/06/aerial-water-cartel-slum-kenya.

2. Sanitation accessibility

19. Ending open defecation is crucial in the successful achievement of the sanitation-related targets of Goal 6. It is a challenging task in many developing countries, particularly in rural areas, due to difficulties in financing the construction of properly equipped toilets and a general lack of awareness among communities of the health-related and environmental implications of open defecation. However, it is far from impossible. For example, in India, the Swachh Bharat Mission, combining modern technology and innovative governance with leadership commitments at the highest political level, has successfully provided a basic sanitation service to a large population; studies have verified the positive net benefits of the Mission across a range of indicators, notably, improvement in the health status of the served population.[19]

20. Toilet flushing accounts for 30 per cent of household water consumption.[20] All sanitation solutions involving sewers require processing in water-based treatment plants. Water-saving toilet technologies can thus generate substantial water savings and avoid waterway pollution, while providing additional opportunities by turning human waste into energy or organic fertilisers for crops. In this regard, a global partnership campaign launched in 2011 aims to "reinvent the toilet" by funding research and development and promoting the commercialization of non-sewer solutions, whereby candidate solutions must have a low level of water use or not use water and ensure the local safe treatment of waste.[21]. One recipient of assistance in this regard, a start-up company in Sweden, invented an easy-to-install, odour-free, water-free, sewage-free, energy-free and low-maintenance portable toilet solution that can be used temporarily or permanently and employs a special formulated bacterial culture to treat human waste and transform it into natural liquid fertilizer that can be used to improve agricultural outcomes.[22] Portable toilet solutions have long been widely used as temporary toilets at short-term events. After several years of incremental innovation and design improvements, the benefits of portable toilets now include the proper disposal of waste and lower levels of water use; some do not use any water. This increases their attractiveness as more permanent solutions in the search for universal access to sanitation, in addition to creating opportunities for employment and business development.

21. Reinvented toilets and installations represent solutions in two ways, namely, they can serve as an accelerated solution to closing the Goals-related sanitation deficit and low levels of water use or non-use of water is also advantageous in the context of water scarcity, which is becoming a worldwide phenomenon. Such solutions represent a key adaptation measure with regard to increased water stress, as the impacts of climate change increase. In addition, they offer a low-carbon alternative to traditional sanitation, in line with the aim of increasing climate resilience globally. In developing countries, sanitation and wastewater treatment systems are not ubiquitous and there is a need for easy-to-install sewage treatment facilities. Small-scale modular wastewater treatment plants or independent sewage treatment plants bring innovation to areas without sanitation and wastewater treatment systems, with benefits for human health and the environment. For example, in Malaysia, a project in a coastal village aims to reduce wastewater pollution; better quality water can sustain marine-related economies and the project is expected to contribute to the development of policies for the long-term conservation of coastal water quality and for addressing wastewater pollution.[23]

[19] G Dandabathula, P Bhardwaj, M Burra, PVVP Rao, and SS Rao, 2019, Impact assessment of India's Swachh Bharat Mission: Clean India Campaign on acute diarrheal disease outbreaks – Yes, there is a positive change, *Journal of Family Medicine and Primary Care*, 8(3):1202–1208.

[20] M Madzia, 2019, Reduction of treated water use through application of rainwater tanks in households, *Journal of Ecological Engineering*, 20(9):156–161.

[21] See https://www.gatesfoundation.org/our-work/programs/global-growth-and-opportunity/water-sanitation-and-hygiene/reinvent-the-toilet-challenge-and-expo.

[22] Contribution from the World Tourism Organization.

[23] Contribution from UNEP.

3. Climate change impacts on water supply: mitigation and adaptation

22. Floods and droughts driven by climate change, which, as shown in 2022, now affect all continents, are among the most critical events influencing the availability of water resources and, in turn, the adequate supply of clean water for drinking and sanitation purposes. Water scarcity is projected to rise due to climate change. Over 1.7 billion people currently live in river basins where water use exceeds recharge. Developing countries face increasing water shortage challenges, for example, Türkiye which, unless water resources are used more effectively and efficiently, is likely to become a water-scarce country in the 2030s.[24]

23. In 2021, a survey of leaders in water management from 86 countries, with a combined population of over 6 billion, showed that the greatest perceived risk in water management was climate change; 80 per cent of respondents ranked climate change among the top three perceived risks. Management of water demand, reduction of water losses and reuse of treated wastewater are key to mitigating and managing the risks from climate change. In addition, as the water sector is the most essential sector in improving the climate resilience of communities and ecosystems, it is important for national climate planners and decision-makers to integrate water management into the responses set out in national adaptation plans and nationally determined contributions.[25]

24. Countries are strengthening efforts and commitments to addressing water supply challenges due to climate change. For example, in Austria, geoelectric analysis is used in areas in which knowledge of the subsoil water supply and its changes is relevant, including demarcation of landslide areas, development of early warning systems and exploration of groundwater; a combination of meteorological-climatological and geological-geophysical analytical tools are being explored through the Geo Sphere programme. In Brazil, dedicated public policies and initiatives have been implemented to reduce losses in the water supply system. In India, the Government has implemented the Water Technology Initiative, to promote water supply from sustainable sources, recycling and the reuse of water, benefiting 200,000 people to date.[26]

25. The intersection between weather and climate data with subsoil saturation data has potential with regard to innovation, particularly in assessing the effects of climate change on the future availability of groundwater resources. Hydrogeological approaches with a strong climatological dimension can therefore be effective in climate change mitigation and adaptation. Early warning systems facilitate the development of natural disaster readiness and response mechanisms. Low-technology innovative systems involving community participation and citizen science with greater levels of community agency and effective partnerships can have beneficial impacts. For example, in South Africa, in April 2022, the use of a community-based early warning system for floods ensured zero loss of life during a "rain bomb" weather event.[27]

26. Natural disasters usually lead to water-related disasters, which often have cross-border dimensions requiring strong regional cooperation. In the United Nations system, regional commissions and several agencies have developed programmes to promote technological and innovative solutions in building resilience to water-related disasters. For example, the Economic and Social Commission for Asia and the Pacific promotes regional cooperation through a space-based drought monitoring mechanism, providing participating countries with timely and free access to data and capacity-building support. The United Nations Office for Disaster Risk Reduction is seeking to foster synergies among disaster reduction activities, including the provision of early warning systems in the event of flooding and droughts that affect water supply at the national and regional levels. The United Nations Platform for Space-based Information for Disaster Management and

[24] Contribution from the Government of Türkiye.

[25] See https://www.adelphi.de/en/publication/stop-floating-start-swimming and https://www.alliance4water.org/wateringthendcs.

[26] Contributions from the Governments of Austria, Brazil and India.

[27] See https://theconversation.com/early-warnings-for-floods-in-south-africa-engineering-for-future-climate-change-181556.

Emergency Response makes available space-based scientific knowledge and technologies for disaster management.[28]

4. Data gathering and forecasting for water and sanitation security

27. Inadequate water quality continues to pose major threats to human health. Continuous monitoring is necessary to control water characteristics; identify patterns, trends and emerging problems; determine whether pollution control programmes are working; design better pollution control efforts; and effectively address emergencies such as floods and spills. Traditional monitoring methodology involving on-site water sampling and laboratorial analyses, although accurate, is costly and time-consuming and only assesses the situation at the instance and location at which samples are obtained.

28. Technological and innovative solutions offer ways to ensure water quality and safety more cheaply and efficiently, as shown in various regions and countries. For example, in Central and South America, a joint initiative between several States has established an online up-to-date and verified information tool on existing rural water supply and sanitation services, to increase cross-border cooperation among countries with similar rural water and sanitation systems.[29] In Egypt, an online system to monitor pollution loads in wastewater discharge from enterprises has been established.[30] In most developing countries, rapid population growth without the parallel development of urban water treatment infrastructure poses challenges for utility companies, which are unable to properly maintain systems. Online monitoring systems ease the burden on competent authorities that need to regularly monitor potable and ambient water quality; facilitate the forecast and management of incidents affecting the quality of watersheds; and reduce intervention response times.

29. Interactions between water quality and hydrology, hydrodynamics, morphology and ecology are complex, and water source protection is essential in ensuring water quality. For example, in China, a systematic technology-centred approach to protecting water sources has been introduced, involving environmental surveys of source zones, analyses of pollution origins and risks and the use of zone delineation methods. Satellite-based remote sensing offers high-resolution information on the spatial distribution of risk factors in water source zones and, through the use of automatic monitoring at source zones, real-time online early warning and monitoring is conducted of particular pollutants, including heavy metals and volatile organic compounds, rather than the use of traditional, less-precise control parameters.[31] In Hungary, a high-resolution fifth-generation urban precipitation monitoring system, informed by studies in fluvial and lacustrine systems, has been developed, encompassing the drinking water supply network alongside hydrodynamic models, to control biological wastewater treatment processes.[32]

30. The capacity to develop highly accurate models increases the ability of policymakers to anticipate the effects of decisions. For example, UNRISD has funded and initiated the development of a context-sensitive sustainable development performance indicator on sustainable water use at the facility level. The indicator provides a low-cost and scalable method for establishing sustainable water allocation for enterprises based on the hydrological, economic and demographic contexts of their facilities. Its simplicity allows it to be scaled up easily and disseminated widely among enterprises or by Governments.[33]

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[28] UNCTAD, 2019, *The Role of Science, Technology and Innovation in Building Resilient Communities, Including through the Contribution of Citizen Science* (United Nations publication, Geneva).

[29] See https://globalsiasar.org.

[30] Contribution from the Government of Egypt.

[31] Contribution from the Government of China.

[32] Contribution from the Government of Hungary.

[33] Contribution from UNRISD.

B. Technological and innovative solutions for integrated water resources management

31. Water is a key driver of social and economic development. It is fundamental in the maintenance and integrity of the natural environment. As a vital natural resource, water should not be considered in isolation. Integrated water resources management considers the various users and uses of water with a view to promoting positive social, economic and environmental impacts at all levels. Governments and private sector actors are facing increasing difficulties in deciding on water allocation and must apportion diminishing supplies according to ever-increasing demands, as demographic and climatic changes increase water stress. The traditional, fragmented management approach is no longer viable and a more holistic approach is essential. Technological and innovative solutions enable different stakeholders, from water utilities to businesses and citizens, to implement more efficient data-driven water management.

1. Hydrological observation systems

32. Hydrological data help to describe hydrological cycles and can be used to better manage water resources by providing information on water quantity and quality, thereby enhancing delivery and research. For example, the World Meteorological Organization open-source hydrological observing system, which collects reliable hydrometeorological data using big data and artificial intelligence, is a tool that can be used in water resources planning and decision-making, including for early warning systems for floods and droughts, for integration into hydrological and climate applications and services and for research; it has been used in three projects in the Arctic basin, the Dominican Republic and the La Plata River basin by Argentina, the Plurinational State of Bolivia, Brazil, Paraguay and Uruguay.[34]

2. Water, energy and agriculture nexus

33. The water sector is one of the oldest users and producers of energy. Water is an input in almost all production, whether agricultural or industrial. This creates a web of interdependencies, constraints, synergies and resource contests that are key in numerous pressing global challenges.[35] Water resource development and management through nexus approaches is therefore central in sustainable growth and poverty alleviation. At the nexus of energy, hydropower is an investment of choice as, alongside energy production, most hydropower projects create water storage and flood control mechanisms and promote agricultural, industrial and urban development. The potential of such energy generation projects has increased substantively due to progress in science, technology and innovation.

34. Solar-powered water and sanitation systems have been installed to leverage the potential of this nexus. For example, in Ethiopia, UNIDO, adopting innovative technologies from Japan, has set up a solar-powered filtration system in a rural area, to provide clean water under conditions of equality and gender equity, fostering the development of community-level technical capacity to independently operate the system and the improvement of public health awareness. In Latvia, renewable energy resources, notably solar power plants, have been used to produce electricity for self-consumption by water supply enterprises, reducing energy expenses and thereby reducing water prices and enhancing consumer interest in centralized water supply.[36]

35. Agriculture accounts for 70 per cent of water withdrawal worldwide. By 2050, population growth and climate targets will require global agriculture to produce 70 per cent more food and, as part of this, production in developing countries will need to almost

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[34] E Boldrini, S Nativi, S Pecora, I Chernov and P Mazzetti, 2022, Multi-scale hydrological system-of-systems realized through World Meteorological Organization Hydrological Observing System: The brokering framework, *International Journal of Digital Earth*, 15(1):1259–1289. See https://public.wmo.int/en/our-mandate/water/whos.

[35] See https://intelligence.weforum.org/topics/a1Gb00000015MLgEAM.

[36] Contributions from the Government of Latvia and UNIDO.

double.[37] This requires either an increase in the amount of water abstracted for irrigating 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, including through circular economy approaches to water. 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.

36. A project on agrophotovoltaics in the Gambia and Mali provides an example of the use of science, technology and innovation in water management to ensure food security. The project uses solar power systems to improve access to water not only for drinking but also for agriculture, to ensure food security, and is expected to maximize efficiency and sustainability in water usage through the use of intelligent systems incorporating smart sensors, microcontrollers and the Internet of things. Real-time data access aids the monitoring of weather, water demand and water allocation in agriculture.[38]

37. Inefficient water use, water pollution, climate change and increasing global water demand put agriculture under pressure, among both commercial producers and smallholders. For example, in the Russian Federation, the Government has implemented Schemes of Integrated Use and Protection of Water Bodies, employing scientific and technological approaches to water management; the schemes assess the admissible anthropogenic load on water bodies and identify future water resources needs and actions required to protect water reservoirs.[39] In Switzerland, the Agency for Development and Cooperation is building on experiences in this area by providing SwF5.5 million to support projects in Africa on ecologically sustainable water management in smallholder agriculture and food systems.[40]

3. Social innovation and the circular economy

38. Technological innovation is significant in assisting countries in conducting integrated water resources management efficiently and effectively, but social innovation is also necessary, to ensure sustainable management. For example, in Kenya, social innovation spurred the development of a participatory solution to improving access to clean water in informal settlements in Nairobi; the initiative emphasizes bottom-linked governance, through collaboration among community-based groups and a human rights organization, to negotiate with State agencies on the provision of water and sanitation services and provide grassroots awareness-raising campaigns and mobilization workshops involving technical training and infrastructure construction.[41]

39. Circular economy approaches to water and sanitation are gaining attention, as they allow countries to move beyond a paradigm that defines water resources by reference to freshwater. Using adequately treated wastewater resources, notably for agriculture, circular economy approaches significantly increase the elements constituting the water resources base. In a context of growing water stress due to climate change and demographic changes, such an increase is key in making the most of limited water resources and managing them such that competing needs are best met. Such an approach, however, necessitates distinct financial, institutional, environmental, technical, social and health-related conditions. Innovative water management and governance requires as much attention as is given to infrastructure.[42]

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[37] See https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf.

[38] Contribution from the United Nations University Institute for Environment and Human Security.

[39] Contribution from the Government of the Russian Federation.

[40] See https://www.eda.admin.ch/deza/en/home/themes-sdc/water/water-people.html.

[41] E Wamuchiru and F Moulaert, 2017, Thinking through Almolin: The community biocentre approach in water and sewerage service provision in Nairobi’s informal settlements, *Journal of Environmental Planning and Management*, 61(12):2166–2185.

[42] Contribution from the International Water Management Institute.

C. Technological and innovative solutions for gender equity

40. Issues related to water and sanitation have an adverse and disproportionate impact on women and girls. In developing countries, women and girls are generally responsible for obtaining water; this can be a dangerous, time-consuming and physically demanding task.[43] Studies indicate that in some countries, the average single trip to the nearest water source takes over one hour. Limited access to water and sanitation facilities and services can lead to the deterioration of physical and psychological health-related outcomes. Obtaining water over long distances or having to use water and sanitation facilities that are not on premises also exposes women and girls to risks of physical and sexual violence.[44] In addition, one in three schools globally lacks access to basic water and sanitation and, therefore, girls in particular stand to lose access to education.[45]

41. Technological and innovative solutions that bring water closer to the home empower women by alleviating or freeing them from tasks related to water collection and treatment. In India, the Ti Bus initiative, aimed at addressing gender-related sanitation issues in the city of Pune, whereby women lacked access to safe and clean public lavatories, provides such lavatories for women in refurbished buses.[46] In Mozambique, in the village of Ndombe, a solar-powered water pumping system installed to enhance irrigation systems and increase crop yields allowed women to sell produce to increase incomes, helped them improve their diets and reduce malnutrition and empowered them to be active in other areas.[47]

42. Building capacity among women is critical for their empowerment and in ensuring better water management. However, doing so in environments with entrenched traditional gender roles is often challenging. For example, the Uplifting Women's Participation in Water-related Decision-making Project of the United States Agency for International Development aimed to empower women in the United Republic of Tanzania by promoting their inclusion in water management decision-making processes; a targeted series of workshops supported by appropriate materials, helped to significantly increase women's participation in decision-making and water management.[48] Other examples of successful projects showcase different tools. For example, in Bangladesh, a World Bank project involving microfinancing and sanitation-related grants for household facilities has led to empowering outcomes.[49] The scaling up of such tools remains a challenge.

43. With greater levels of water security, women and girls can be freed from the burden of obtaining water for the household and are able to be more active in the local economy or have greater access to education. In turn, empowered women can enhance the development of their families, economies and societies.

D. Frontier technologies used in water and sanitation

44. In many cases, simple and well-established water management solutions can be used to address primary access to clean water and sanitation, such as delivering drinking water solutions to populations. However, other aspects of water and sanitation management may require more input from new and emerging technologies. Rapid advances in frontier technologies, including the use of drone technologies, artificial intelligence and the Internet of things, satellite-based technologies and digital twins, have the potential to assist significantly in the achievement of Goal 6.

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[43] See https://www.unwater.org/water-facts/water-and-gender.
[44] Assefa et al., 2021; Scherer et al., 2021.
[45] See https://www.wateraid.org/au/articles/one-in-three-schools-around-the-world-have-no-clean-water-or-toilets.
[46] See https://www.3sindia.com/innovations.
[47] Contribution from UN-Women.
[48] See https://www.globalwaters.org/wherewework/africa/tanzania.
[49] See https://blogs.worldbank.org/endpovertyinsouthasia/enhancing-womens-access-water-sanitation-and-hygiene-bangladesh.

45. Drones can provide aerial views, to assist in water and sanitation management. For example, in the Dominican Republic, the National Institute of Safe Drinking Water and Sewerage relies on drone technology for data management, information exchange and decision-making in the design, redesign, treatment and maintenance of drinking water and sanitation systems.[50] Drones can also play an important role in monitoring in the event of natural disasters. For example, in Belize, drones are used in the hydrological sector to observe the spatial extent of floods and identify ideal locations for monitoring stations. In the Gambia, drones are used to undertake long-term climate risk assessments and to update outdated and inaccurate topographic data. In other countries, for example in Peru, drones are used to monitor water quality and infrastructure, given their advantages in providing observations of inaccessible areas of water bodies and vulnerable sites.[51]

46. Water and sanitation management equipped with artificial intelligence, big data and Internet of things technologies can be a catalyst in monitoring progress and accelerating the achievement of Goal 6. One area in this regard is the improvement of water-use efficiency, demand management and leakage control, which is urgently needed, given increasing water stress globally. Smart technologies that use big data, such as smart metering, have proved effective as they can trigger behavioural change among water users by providing real-time information and customized feedback. In Oman, a water leak detection system created in 2020, which takes measurements through autonomous smart meters to collect data on water usage, has resulted in a 15 per cent reduction in water waste.[52] In Latin America and the Caribbean, IABD has created an integrated and quantitative online system to simulate hydrology and water resources management using a combination of smart metering and the Internet of things that, given scenarios of change in climate, land use or population, helps evaluate water quantity and quality and inform infrastructure needs and the design of strategies and projects adaptive to such changes.[53]

47. Satellite-based remote-sensing technology is suitable for near real-time monitoring of the geographical coverage and water quality of inland freshwater systems. The technology can be used to detect eutrophication, light penetration, phytoplankton bloom, chlorophyll level and turbidity, as well as other parameters. For example, in Ethiopia, a new methodology developed by the European Commission Joint Research Centre using satellite-based remote sensing has substantially improved drilling success rates, from under 50 to over 90 per cent; through the scanning and identification of sites with significant potential for groundwater extraction, areas can be identified in which more detailed on-the-ground studies can be conducted. In the Philippines, under the Remote Sensing and Data Science project, a geographic information system plugin has been developed, to train artificial intelligence models to extract features from imagery from satellites; the plugin is available for use by government agencies and academia.[54]

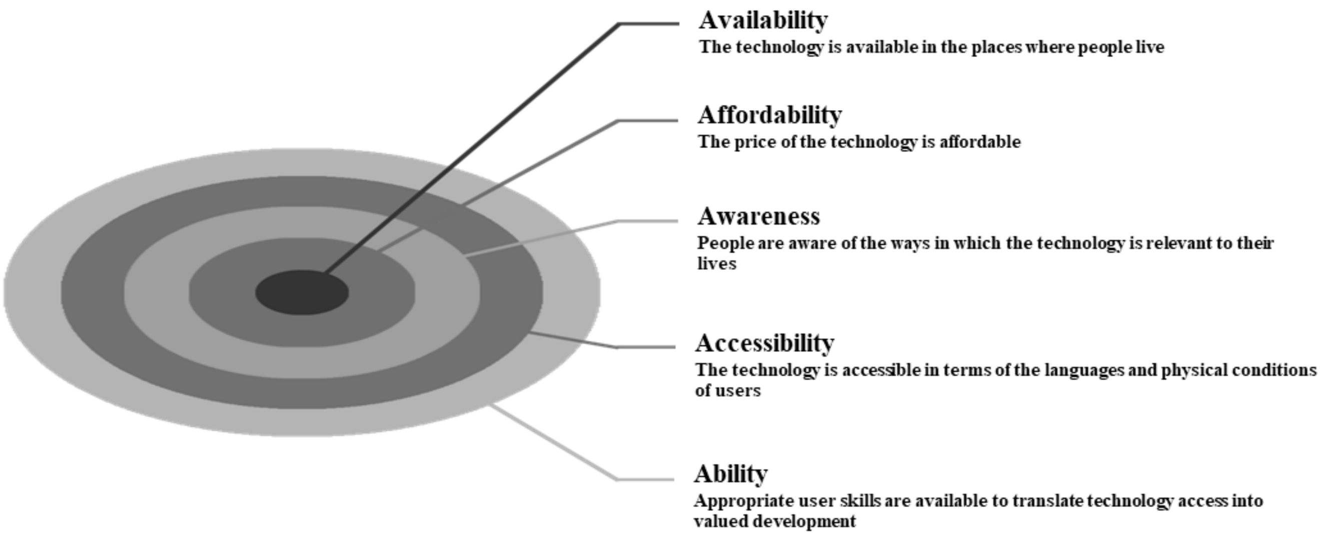
48. Rapid improvements in frontier technologies have led to the deployment of a range of technologies to enhance reliability and efficiency in the provision of services through real-time management and the monitoring of water and sanitation infrastructure and operations and by providing detailed and useful data and analytics. For example, intelligent water management is enabled through the use of digital twins, whereby a virtual duplicate is created of the real asset, which can be used in conjunction with real-time monitoring. This can enable intelligent and dynamic management; the simulation of scenarios, for business continuity and process optimization; and the testing of interventions in the event of emergencies or upgrades.

[50] Contribution from the Government of the Dominican Republic.
[51] Contributions from the Governments of Belize, the Gambia and Peru.
[52] Contribution from the Government of Oman.
[53] Contribution from IADB.
[54] Contributions from the Government of the Philippines and WHO.

III. Translating science, technology and innovation into impacts on the ground

49. Despite the rapid production of knowledge and concrete solutions, water and sanitation practitioners generally either do not find the majority of scientific knowledge accessible or find that it is not in a sufficiently usable form to inform decision-making. There is an urgent need to translate science, technology and innovation into real-world impacts. Countries need to invest in the science of implementation, to benefit from the solutions developed by science, technology and innovation enterprises. A lower level of availability of knowledge solutions closer to the implementation phase presents a major challenge. Responsible factors include the higher costs of innovation projects, the difficulty of attracting investment partners due to the higher risk profiles of new solutions and the lack of capacity to support new solution platforms. Challenges in the implementation of scientific knowledge or technological solutions with regard to water and sanitation can largely be addressed by focusing on four key dimensions, the first of which, access, comprises "five As" (figure 3). Practical approaches to implementing technological solutions must first address non-technological barriers to accessing the technology. For example, a solar-powered water pumping system 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 without training being provided. Access to technology can also be restricted by social norms (e.g. for women and ethnic minorities) or geography (e.g. for people in remote areas). Such restrictions must be recognized, considered and addressed.

Figure 3
The five As of technology access



Source: UNCTAD, 2021, *Technology and Innovation Report 2021: Catching Technological Waves – Innovation with Equity* (United Nations publication, sales No. E.21.II.D.8, Geneva).

50. The second dimension is transdisciplinarity. Analytical science and engineering products are crucial in finding water-related solutions, yet implementation and sustainability rely heavily on social factors such as behaviour, culture, economy, policy and governance. A capable water team must have both repositories of knowledge and science-based solutions in these domains and skilled non-technical expertise that can help ensure successful implementation.

51. The third dimension is investment in nexus approaches. Embracing the connectivity between water and other sectors is essential in the development of sustainable and efficient solutions, as improvements in each area can have positive externalities in others, and a failure to sufficiently consider the interdependency of different sectors may lead to positive outcomes in one sector but unintended negative consequences in others. A nexus approach can make it possible to attract a broader investment community and benefit from more attractive cost and benefit ratios. Water-centred nexus approaches are therefore fundamental in the achievement of Goal 6, while simultaneously contributing to the achievement of other Goals such as those on hunger, energy, climate action and partnerships for the Goals. For example, agriculture is the greatest consumer of water resources and, at the same time, needs to provide more food to meet growing global demand. Appropriate water management should provide sufficient water for agricultural practices without depleting stored water required for other purposes.

52. The fourth dimension is technology and knowledge-sharing among countries, to effectively address water and sanitation-related challenges. A range of global partnerships, platforms and cooperation models have been set up under North–South, South–South and triangular regional and international cooperation, not only to support access to science, technology and innovation but also to enhance knowledge-sharing that fosters the scaling up of good practices domestically and inspires the replication and adaptation of successful technological, social and financial innovations internationally (see box). However, to accelerate progress in the Decade of Action, under the five pillars in the Global Acceleration Framework, to achieve Goal 6 by 2030, there is a need to facilitate much greater levels of technology access, knowledge transfer and capacity-building and to make such opportunities better structured, more organized and less haphazard.

Global cooperation models through which to achieve Goal 6

Actors engaged in knowledge-sharing and dissemination with regard to water and sanitation include multilateral organizations, development agencies and dedicated networks. These platforms generally involve partnerships and combine an online platform with an extensive network that may reach from a local to a global level. They also share knowledge and build capacity through dedicated programmes.

Multilaterally, UN-Water, which comprises over 30 United Nations entities, has the broadest thematic scope, sharing experiences with those of others, and operating the Activity Information System, an online platform for sharing information on water-related projects and learning initiatives. In the United Nations system, the Commission on Science and Technology for Development serves as a multilateral platform at which national lessons learned and best practices in leveraging science, technology and innovation, to address water and sanitation-related challenges, may be shared, as well as for promoting international cooperation through technical assistance programmes in developing countries, including with regard to accessing knowledge and technology transfer. The World Summit on the Information Society, with Forums co-organized by ITU, UNCTAD, the United Nations Development Programme and the United Nations Educational, Scientific and Cultural Organization, has Action Lines on the Sustainable Development Goals, including one on Goal 6 that links with Action Lines on access to information, capacity-building, information and communications technology applications, electronic science and cultural diversity and local contexts.

Regional initiatives have an important role in ensuring access to safe water and sanitation. For example, in Latin America, the Water Funds Partnership, with innovation through institutional and financial mechanisms at its centre, promotes public–private partnerships in the conservation of watersheds, to improve water security; core partners include the Government of Germany, the Global Environment Facility and IADB. The partnership has 26 funds operating in several countries and has benefited over 105,000 families to date. In the European Union, the Water Initiative Plus for the Eastern Partnership programme has benefited countries such as Belarus through intensive participation in topical national and regional reviews and capacity-building activities.

A number of countries focus on water and sanitation under international and bilateral cooperation agendas. For example, in Japan, technology-sharing and capacity-building is conducted in countries using technological solutions developed under the Kumamoto Initiative for Water including, among others, the use of artificial intelligence and the Internet of things to support development and provide quality infrastructure in Asia and the Pacific, and in implementing climate change mitigation and adaptation measures through various infrastructure projects. Among developing countries, South Africa, through the Water Research Commission, has engaged with multiple international partners to share expertise in water and sanitation.

Source: Contributions from the Governments of Belarus, Cuba, Japan, South Africa and Thailand, as well as IADB and ITU.

IV. Suggestions for consideration

53. The General Assembly and the Human Rights Council have recognized the right to safe drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights.[55] Goal 6 has a broader, integrated approach to addressing the issue of water and sanitation, going beyond merely access to these services, with a view to ensuring the sustainability of water supply and sanitation services. A number of policy considerations have the potential to assist countries in efforts to harness science, technology and innovation in ensuring access to safe water and sanitation for sustainable development.

54. Member States may wish to consider the following suggestions:

(a) Cultivate and empower local research and innovation ecosystems. Build technology acceptance and promote digital mindsets and capacity-building skills, while carefully considering the social, cultural, financial, geographical and climatic conditions in target communities, including the ability to operate and maintain technological solutions;

(b) Develop close partnerships between practitioners and users, with a focus on community involvement. Provide assistance to grassroots and community-led participatory initiatives, to strengthen local water and sanitation resources ownership and enhance water governance by bringing practitioners and users together;

(c) Prioritize the development, distribution and implementation of modular, off-grid and decentralized low-technology solutions through monitoring and accounting systems and citizen science, for water collection, purification and waste disposal. Extend access in last-mile communities, particularly in rural areas, using affordable, context-appropriate and flexible technological solutions;

(d) Transform infrastructure and services delivery, for gender equality. Promote appropriate sanitation services delivery in households and public spaces, to alleviate gender-based burdens and discrimination. Design water and sanitation policies and projects with a gender lens, ensuring they do not perpetuate gender disparities, based on data disaggregated by gender;

(e) Introduce or overhaul data infrastructure in water and sanitation. Establish simple, systemic, human-centric and multi-stakeholder collaborative systems, to support more comprehensive water resources assessments, improve decision-making and minimize water loss and waste;

(f) Scale up good practices, for universal access to water and sanitation and integrated water resources management with proven track records. Assess the factors that hinder or accelerate the local scale up of good practices and seek to address or promote them appropriately. Explore and promote circular economy approaches to water and sanitation, turning treated wastewater into a water resource where appropriate;

(g) Introduce new, innovative and more equitable financing mechanisms. Adopt blended financing models at the macro level, combined with microfinancing for small-scale

[55] A/RES/64/292.

operators, to foster an enabling environment for a sustainable water business. Increase the attention paid by donors and institutional investors to Goal 6, highlighting the essential role of water and sanitation in economic, social and environmental areas in all countries.

55. The international community may wish to consider the following suggestions:

(a) Promote knowledge transfer and capacity-building through North–South, South–South and triangular cooperation. Engage multilateral organizations, development agencies, global networks of actors in water and sanitation and the Commission on Science and Technology for Development, to actively increase the global flow of water and sanitation-related science, technology and innovation knowledge, from current production centres to all member States, and to build synergies between initiatives;

(b) Promote technology transfer between developed and developing countries. Transfer complete packages, including the building of local capacity and capability to operate, maintain and, where needed, adapt them to the local context, in the upgrading of water and sanitation infrastructure or the development of water management in developing countries;

(c) Develop financial mechanisms that promote financial assistance from high-income countries and investment from the private sector to developing countries, particularly the least developed countries, landlocked developing countries and small island developing States, recognizing the cross-cutting role of such mechanisms in achieving the 2030 Agenda for Sustainable Development;

(d) Prepare the global water and sanitation community for the effects of climate change through cooperation and a global focus on increasing climate resilience among water and sanitation systems. Ensure that shared knowledge and science, technology and innovation solutions have built-in climate resilience. Promote cross-sectoral coordination through a nexus approach, such as to the water, energy and agriculture nexus, to exploit interlinkages.