# ACHIEVING SDG 6
## (WATER GOALS):

# CONTRIBUTION FROM ENGINEERING

World Federation of Engineering Organizations
Working Group on Water

LEAVE NO ONE BEHIND

WFEO / FMOI


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# Summary

# Executive Summary

In addition to its unique importance, the United Nations Sustainable Development Goal 6, SDG6 – Clean Water and Sanitation, interacts with several others, namely SDG1 – No Poverty, SDG7 – Affordable and Clean Energy, SDG8 – Decent Work and Economic Growth, SDG11 – Sustainable Cities and Communities, SDG12 – Responsible Consumption and Production and SDG13 – Climate Action.

Climate change is likely to expand the water scarcity areas of the globe, population will continue to grow, but probably at slower rates, and the reduction of the number of persons living on extreme poverty, which has been taking place in the past years, will hopefully continue in the coming years. Population growth will take place mostly at cities, and increases in wealth will translate into higher levels of consumption, particularly of food items requiring more water to be produced. Energy will be ubiquitously needed, and its price will influence the cost of most products, including clean water.

It is very difficult to develop other than emergency engineering solutions for people living in extreme poverty, with an income of less than two dollars per day (Standard of Living Level 1 according to Hansd Rosling 2018), which have been decreasing from nearly 1 billion in 2017, but still far from complete eradication.

However, it will certainly be a major priority to develop long term engineering solutions affordable to people living under eight dollars per day (Standard of Living Level 2), as this group, currently representing almost half of the word population, although decreasing, is likely to remain significant for the next decades. The number of people earning between 8 and 32 dollars per day (Standard of Living Level 3) is increasing to more than a half of the world population and it may be assumed that this group tendentially may be served with conventional urban solutions, which became the rule in developed countries (Standard of Living Level 4, above 32 dollars per day).

Overall, it will be necessary to go on developing long term solutions affordable to all the world population, which success among the poorer will depend on extended national and international solidarity.

In this report we concentrate on innovative solutions for WASH (clean water, sanitation and hygiene), but also on proven engineering solutions still not widely used. As SDG 6 goes beyond WASH, other topics are also addressed.

Conventional engineering solutions, which proved to be successful in the past, are likely to be the rule in the next decade where there is little scarcity, and in the absence of generalized poverty. Indeed, for the developed countries and for an increasing number of developed regions of developing countries, almost without extreme poverty, already served with modern infrastructure, with relatively low, affordable water costs, the future will most likely be business as usual, with a gradual improvement of the existing technologies and engineering solutions, as far as water is concerned.

Poverty will limit the universal access to proper housing, health, education, employment, culture and, also, water. On the other hand, climate change will lead to more severe and frequent droughts, posing a serious risk to poverty reduction worldwide. Fortunately, in the long run, the ultimate solutions for water in dryer areas may be inspired in the ones developed for space stations: endless recycling, or the direct reuse of wastewater as potable water.

Recycling and reuse of wastewater (Namibia, Singapore, Spain, L'Oreal, Hydraloop), desalination (Israel, Singapore, Australia, London, Barcelona and southeast of Spain), sewer tunnel in large cities (London, Singapore, Ottawa, Chicago), abstracting water from the air (Majik Water) and dry toilets (Bill Gates Foundation, Blue Box), are examples of such solutions.

Water pollution has enormous externalized costs, with public health and environmental impacts, which have been accepted as inevitable in the name of economy and jobs, but perhaps there is a viable, although disruptive alternative: endless recycling. Endless recycling would solve two great problems, providing clean water availability while simultaneously reducing water pollution in rivers, lakes and groundwater. This endless recycling could be developed at city level, conveying the sewage to a small number of “water factories” where it would be treated to potable water standards and recycled to the public water supply system. With cheaper energy, namely solar, reuse and desalination will become more viable, but is still unclear if taxation on renewable energy will not revert the currently declining energy production costs.

Recycling could also be developed at the individual house level or at the level of small communities (e.g. apartment building), with the use of dry toilets, the extraction of moisture from the air and rain-water storage, making unnecessary the connection to the public water supply and sewerage systems. Some relatively low-cost solutions already exist (e.g. Sanivation blue box and Majik Water from Kenya), although the widespread use of such solutions will also depend on the evolution of the energy costs. More recycling at the house level would also impact on the future water and wastewater public systems: the renovation and expansion of existing pipelines and sewers would have to be evaluated under different perspectives.

The evaluation of engineering solutions has to include the economic, social and environmental components, and the widespread increase of recycling in water and other innovative solutions will require proper evaluation in the future. Moreover, the more generalized use of some techniques, such as direct water reuse, will require strong communication. The COVID-19 pandemic showed us that humanity can change very quickly, much more rapidly than anyone thought it was possible, and therefore the cultural barriers to direct water reuse will inevitably fade and this alternative water source will be more widely used in areas with serious situations of scarcity.

Although water is ultimately a political issue, the political decisions regarding water must be taken between sound engineering alternatives.

The role of engineers, while participating in water projects (product development, planning, design, project management, construction, operation, maintenance, direction and management of institutions), will certainly be pivotal for the achievement of the SDG6 - Ensure availability and sustainable management of water and sanitation for all.

Engineers are the best prepared professionals to lead the works and subsequent management of the investments necessary to achieve the objectives of SDG6.

Certainly, humanity will have the sufficient collective intelligence to avoid a global catastrophe concerning water. We have solutions already available and increasingly economically viable, making their potential use much more widespread while targeting SDG. If we are unfortunate that water scarcity gets worse, we know at least that these solutions exist and that we depend on ourselves.

As we face the challenges related with SDG6 fulfilment, technological innovation, knowledge management, advanced research and capacity development will generate new tools and approaches, and equally importantly, will accelerate the implementation of existing knowledge and technologies across all countries and regions. WFEO want to contribute to accelerate the journey through this roadmap.

So, ENGINEERING must be considered as an ACCELERATOR to reach this SDG 6.

# 1 Introduction

The Sustainable Development Goals essentially assume that it is possible to reach sustainability in the world in 10 years, including in the water sector.

In technical terms, this is not impossible, as most water projects, except perhaps dams, can be decided, planned, designed, and built in less than five years, under ideal financial and institutional conditions. However, this was also true in the 1970´s, 1980's, 1990's, 2000's and 2010's, when similar global initiatives to solve the world´s water problems in a 10- years span were launched, unfortunately with only limited success.

## Former "next decade" promisses

- United Nations Conference on the Human Environment (1972);
- Unted Nations Water Conference (1977);
- International Drinking Water Supply and Sanitation  Decade (1981-1990);
- International Conference on Water and the Environment (1992);
- The Earth Summit (1992, 2002);
- Millenium Summit (2000);
- United Nations Conference on Sustainable Development, Rio+20 (2012

The framing of this WFEO report was facilitated by a **white paper** under the same title produced during the 32nd UN Water meeting on January 29, 2020 in Rome (2020), according to which:

- The Sustainable Development Goals (SDGs) of Agenda 2030 aim at implementation of necessary changes in order to ensure the survival and prosperity of all people and all forms of life on the planet.
- Several other goals are closely related to water issues including SDG 1 (ending poverty in all its forms), SDG 2 (eliminating hunger and providing food security), SDG 3 (ensuring good health and well-being for all), SDG 7 (affordable, reliable, sustainable and clean energy), SDG 11 (safe, resilient and sustainable cities), SDG 12 (sustainable consumption and production), SDG 13 (climate change), and SDG 15 (biodiversity, forests, deforestation). The problems that led to setting these goals are multi-dimensional and involve potentially conflicting interests, presenting the challenge of how to find win-win solutions.
- Despite progress in developing the field of environmental engineering, billions of people still lack safe water, sanitation and handwashing facilities where a doubling of progress is required to achieve universal access to basic sanitation by 2030.

**The Sustainable Development Goals (SDGs)**, adopted by all United Nations Member States in 2015, are a call for action by all countries to promote prosperity while protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection (ONU 2020b). Therefore, the SDGs intend to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030.

Through the pledge to Leave No One Behind, countries have committed to fast-track progress for those furthest behind first. That is why the SDGs are designed to bring the world to several life-changing 'zeros', including zero poverty, hunger, AIDS and discrimination against women and girls.

The **17 SDGs** are integrated—that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability. **The Goal 6** aims to ensure access to water and sanitation for all.

Sustainable management of water resources and access to safe water and sanitation are essential for unlocking economic growth and productivity, and provide significant leverage for existing investments in health and education. The natural environment e.g. forests, soils and wetlands, contributes to management and regulation of water availability and water quality, strengthening the resilience of watersheds and supports investments in physical infrastructure and institutional and regulatory arrangements for water access, use and disaster preparedness. Protecting and restoring water-related ecosystems and their biodiversity can ensure water purification and water quality standards (UNEP 2020).

Water shortages also undercut food security and the incomes of rural farmers, while improving water management makes national economies, the agriculture and food sectors more resilient to rainfall variability and able to fulfil the needs of growing population.

While substantial progress has been made in increasing access to clean drinking water and sanitation, billions of people—both in urban and rural areas—still lack these basic services. Worldwide, one in four people do not have access to safe drinking water, two out of five people do not have a basic hand-washing facility with soap and water, and more than 673 million people still practice open defecation **(UNWater 2021).**

If we provide affordable equipment and education in hygiene practices, we can stop this senseless suffering and loss of life.

Almost one-tenth of the total burden of waterborne diseases worldwide could be prevented by improvements to drinking water, sanitation, hygiene and water resources management. The following examples refer to global diseases that are preventable if these conditions are met: diarrhoea (1.4 million preventable child deaths annually); malnutrition (860,000 preventable child deaths annually); intestinal nematode infections (2 billion infections affecting one-third of the world's population); lymphatic filariasis (25 million seriously incapacitated people); schistosomiasis (200 million people with preventable infections); trachoma (visual impairments in 5 million people); and malaria (half a million preventable deaths annually) (WHO, 2019).

In addition, emerging and future biological threats can be anticipated, for example: i) other known diseases that can re-emerge; ii) 'new' diseases identified due to new, more sophisticated laboratory methods; iii) real new diseases; iv) changes in disease behaviour; v) changes in environmental conditions; and vi multidrug-resistant microorganisms that may arise.

Anticipated climate change can make these numbers even more dramatic, though their possible spread is unlikely. However, the ability to spread infectious diseases via vector arthropods increases with rising water temperatures. Regions such as Europe and North America, which were previously too cold to support transmission, may experience an inversion of this trend as the rise in water temperature creates favourable conditions for the reproduction of the aforementioned vectors.

The COVID-19 pandemic has demonstrated the critical importance of sanitation, hygiene and adequate access to clean water for preventing and containing diseases. Hand hygiene saves lives. According to the World Health Organization, handwashing is one of the most effective actions you can take to reduce the spread of pathogens and prevent infections, including the COVID-19 virus. Yet billions of people still lack safe water sanitation, and funding is inadequate (ONU 2020a).

The following SDG6 targets and indicators have been defined:

| Targets | Indicators |
|---|---|
| 6.1. By 2030, achieve universal and equitable access to safe and accessible drinking water for all | 6.1.1. Proportion of population using safe-managed drinking water services |
| 6.2. By 2030, obtain access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and vulnerable people | 6.2.1. Proportion of the population using safely managed sanitation services, including a hand washing facility with soap and water |
| 6.3. By 2030, improve water quality by reducing pollution, eliminating waste and minimizing the release of chemicals and hazardous materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally | 6.3.1. Proportion of wastewater safely treated |
| 6.3.2. Proportion of water bodies with good ambient water quality | |
| 6.4. By 2030, substantially increase water use efficiency in all sectors and ensure sustainable withdrawal and supply of fresh water to combat water scarcity and substantially reduce the number of people suffering from water scarcity | 6.4.1. Change in efficiency of water use over time |

| Targets | Indicators |
|---|---|
| 6.4.2. Water stress level: withdrawal of fresh water as a proportion of available fresh water resources | |
| 6.5. By 2030, implement integrated water resources management at all levels, including through cross-border cooperation, as appropriate | 6.5.1. Degree of integrated implementation of water resources management (0-100) |
| 6.5.2. Proportion of the transboundary basin area with an operational arrangement for water cooperation | |
| 6.6. By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes | 6.6.1. Change in the extent of water-related ecosystems over time |
| 6.A. By 2030, expand international cooperation and support for capacity-building in developing countries in activities and programs related to water and sanitation, including abstraction, desalination, water efficiency, wastewater treatment, recycling and reuse technologies | 6.A.1. Proportion of local administrative units with established and operational policies and procedures for the participation of local communities in water and sanitation management. |
| 6.B. Support and strengthen the participation of local communities in improving water and sanitation management | |
| | 6.B.1. Proportion of local administrative units with established and operational policies and procedures for the participation of local communities in water and sanitation management |

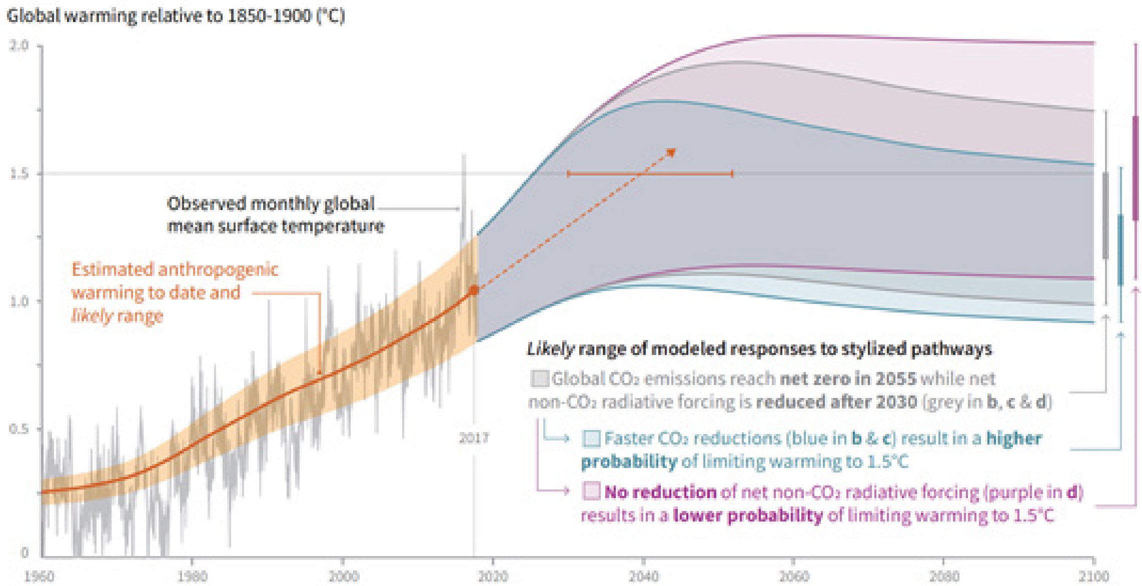
Essentially, these Sustainable Development goals aim at reaching or at least approaching sustainability for mankind within 10 years.

Although SDGs were based on the results of very participated technical meetings, the final declarations are necessarily political, and reflect difficult consensus between leaders of over two hundred countries with very different dimensions, population, natural resources, climate and, ultimately, very different levels of GDP per capita.

Water is a complex and political issue. There always have been water problems to be solved and there will always be in the future, simply because water and life are two faces of the same coin. Water is interrelated to population, consumption patterns of people, energy prices, world environment and climate change. Moreover, climate change depends very much on the evolution of the world population, on the future consumption patterns all over the world and on the predictable shift to non-fossil energy production.


Beyond non-predictable forces of nature, climate change appears as the most critical factor under human control to reach sustainability of mankind. This was becoming clear to lay people before COVID19 and, although the pandemics appears now at the top of threatening perceptions, climate change will most likely regain its former status.

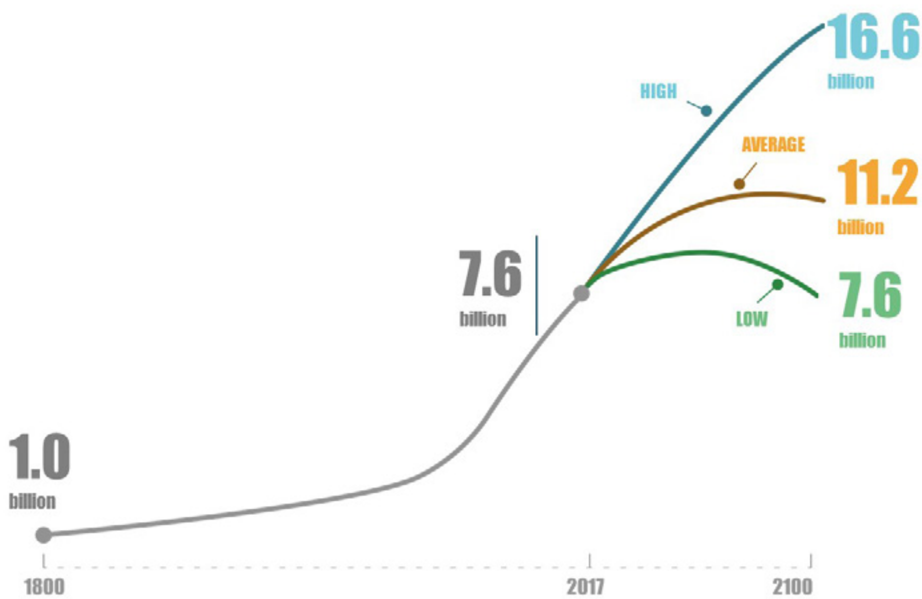
According to the 2018 IPPC Special Report on Global Warming, human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.



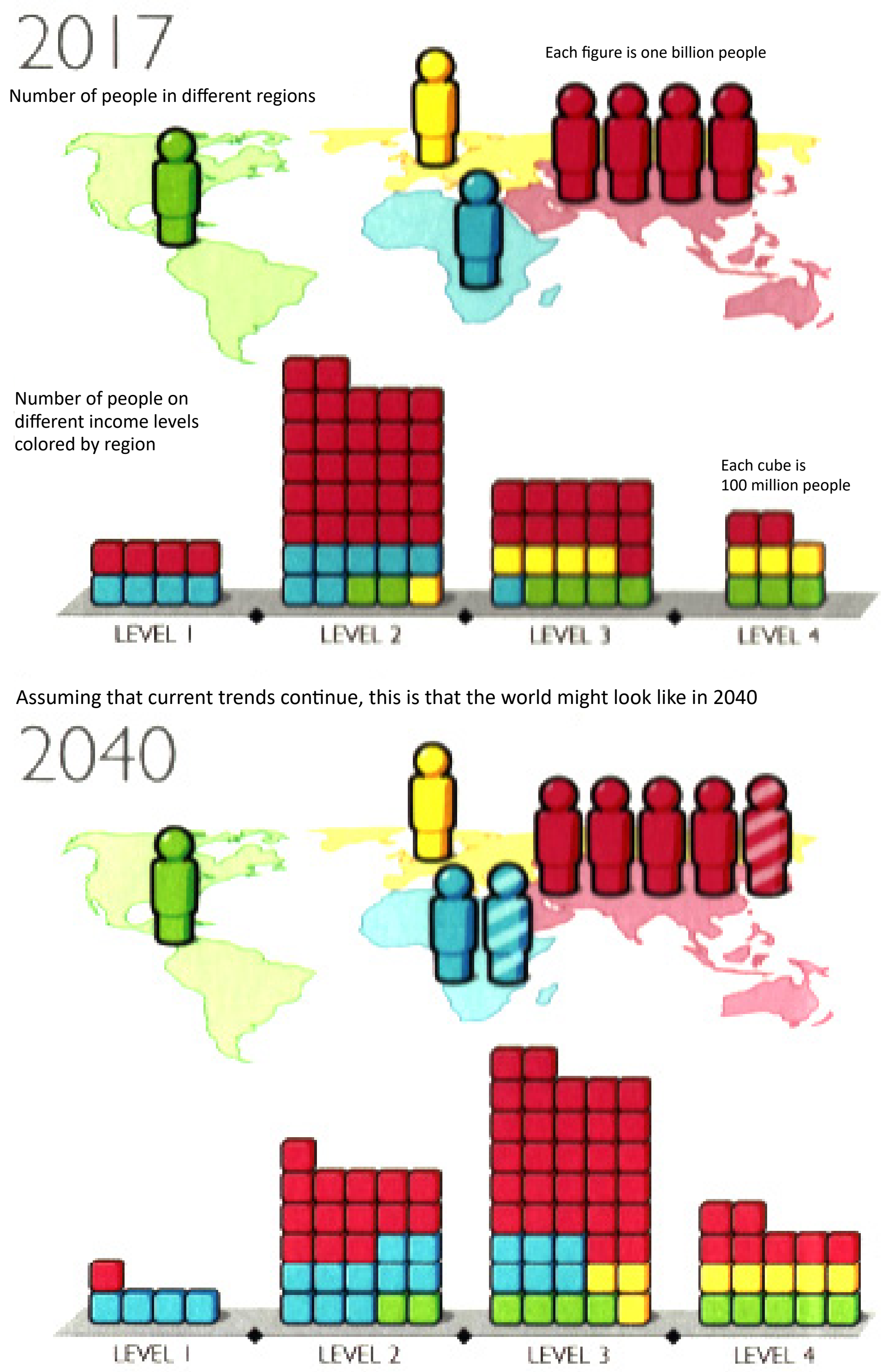

The world population is currently approaching 8 billion, with 80% in developing countries. The growth, and consequently the water demand and water problems, is higher in the informal settlements of larger megacities of developing countries.

Obviously, the nature and extension of the future water problems will depend primarily on the evolution of the population. The situation will be completely different if the population remains at the current level or if it doubles by 2100.


Hansd Rosling (2018) proposed a classification of the population in four levels of income: level 1 (<2 USD/capita), level 2 (< 8USD/capita), level 3(<32USD/capita) and level 4 (> USD/per capita). It is expected that there is a shift towards higher standards of living, certainly good news in terms of reduction of poverty, but this also mean higher consumption of resources, including water, and CO2 production. The current definition of the water cycle assumes that less than 1% of the existing water in the world is available for human use.



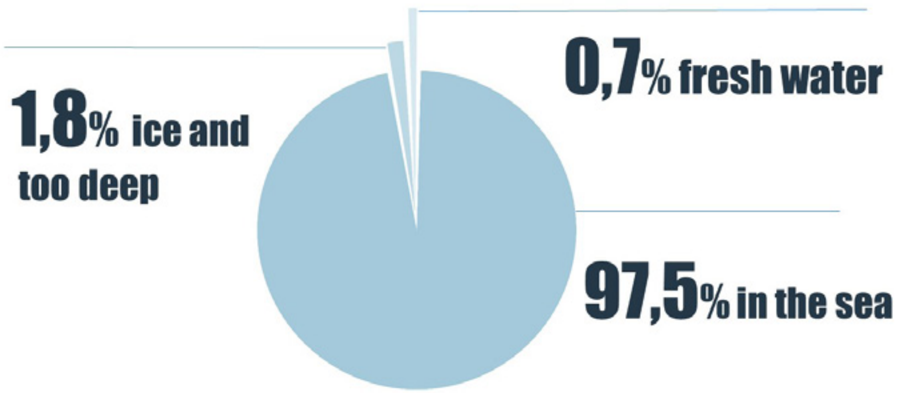
## PEOPLE BY REGION AND INCOME




source: Gapminder [1,3,8] based on PovcalNet UN-Pop [1], IMF [1] & van Zanden [1]

SOURCE: FACT FUL NESS – HANSD ROSLING - 2018

However, there are engineering solutions to reuse wastewater and to desalinate sea and brackish water, making the supply virtually infinite. So, in addition to the traditional water resources, planning and management can be enriched with additional sources: reused water and desalinated water.




This report on the role of engineers to achieve SDG6 goals, prepared by the Water Working Group of WFEO, does not try to quantify the resources necessary to achieve such goals. This would be a virtually an impossible exercise considering the lack of data available and the variability of site and country specific situations.

The report focuses on innovation towards reaching SDG6 targets, but does not attempt to describe in detail the technologies, methodologies and science behind the engineering solutions presented, some of them still at the prototype stage.

The report is a collaborative work carried out on a voluntary basis by engineers of WFEO member countries and regions, under the leadership of its Working Group on Water. It was produced by a multidisciplinary team of engineers and recurring also to contributions from other professional areas, as water is a multidisciplinary issue.

Engineering problems and solutions are time and site specific and typically involve public or private institutions: municipal, regional, national, public, private, regulators, utilities, banks, donors, etc.

There are 5 continents, over 200 countries, some of the size of continents and millions of decision makers and professional engineers involved at each moment in the solution or real problems. Although it is not possible to be exhaustive and to anticipate every possible problem or solution, there are types of problems and solutions that can be defined and made available through this report to decision makers and engineers involved in the solutions.

We hope this report passes a message of optimism, that there are engineering solutions to most present and future water problems. Nevertheless, we are aware that water is also a political issue and that ultimate decisions are political, albeit preferably between alternatives supported on sound engineering options.

**"There are and there will be engineering solutions to most water problems"**

In addition to the present introduction, this report includes a summary of the current situation and forecast (Chapter 2), a description of the possible engineer's contribution to the SDG6 goals (Chapter 3), the presentation of some of the technologies used and in development for future use in the water sector (Chapter 4) and conclusions (Chapter 5).

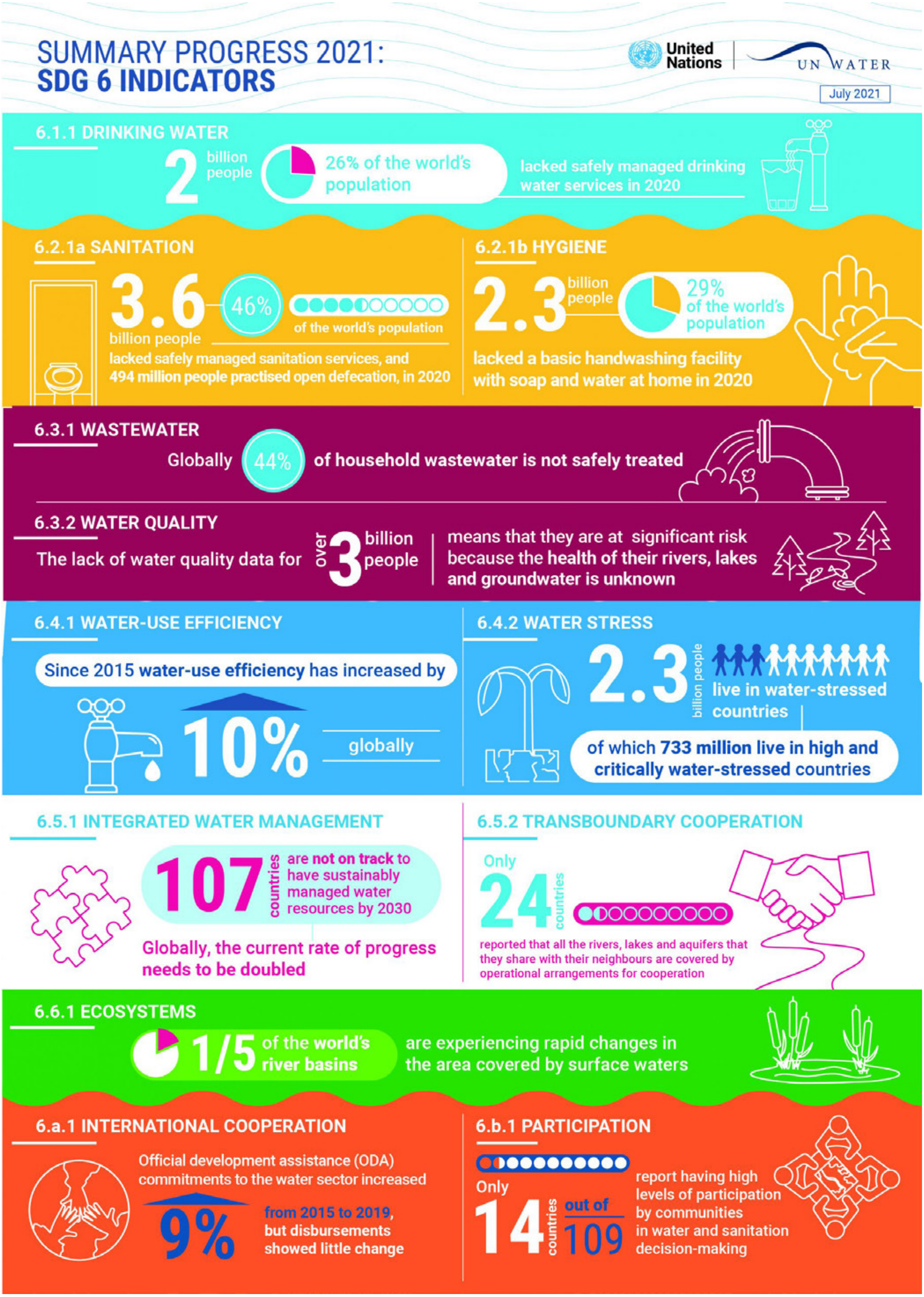
# 2 Situation and Forecast

There is a 2021 **UN report** monitoring the progress towards the eight SDG 6 targets. The report is based on country data for the several indicators used, compiled and verified by the responsible UN organizations, and its main results are presented in the infographics depicted in the next page[1]. Although validated data for many countries are missing for those and other indicators, in summary:

- 26% of the world population da population lack access to safely managed drinking water services and 55% lack access to safely managed sanitation facilities (in 2020).
- Women and girls are responsible for water collection in 80 per cent of households without access to water on premises.
- At least 494 million people continue to practice open defecation in 2020.
- 40% of the world population da population lack access to a basic handwashing facility with soap and water in 2020.
- Less than 50% of domestic wastewater is safely treated (40%).
- Over 3 billion people are at risk because the health of their rivers, lakes and groundwater is unknown.
- 2.3 billion people live in water-stressed countries. 733 million live in high and critically water-stressed countries. Over 1.7 billion people are currently living in river basins where water use exceeds recharge.
- 88 countries are on track to have sustainable managed water Resources by 2030. Globally, the rate of progress has to be doubled.

[1] Donwloaded from: https://www.unwater.org/app/uploads/2021/03/Infographics_Progress-on-water-and-sanitation.png

- Only 24 countries reported that all water bodies shared with neighbouring countries are covered by cooperation agreements.
- 1/5 of the world´s river basins area experiencing rapid changes in the area covered by surface waters.
- Official development assistance commitments to the water sector increased 11% from 2015 to 2019, but disbursements only increased by 3%.
- Only 14 out of 109 countries report having high levels of participation by communities in water and sanitation decision-making.
- Each day, nearly 1,000 children die due to preventable water and sanitation-related diarrheal diseases.
- More than 80 per cent of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal.
- Approximately 70 per cent of all water abstracted from rivers, lakes and aquifers is used for irrigation
- Floods and other water-related disasters account for 70 per cent of all deaths related to natural disasters.



SUMMARY PROGRESS 2021:
SDG 6 INDICATORS
United Nations
UN WATER
July 2021
6.1.1 DRINKING WATER
2 billion people
26% of the world's population
lacked safely managed drinking water services in 2020
6.2.1a SANITATION
3.6 billion people
46%
of the world's population
lacked safely managed sanitation services, and 494 million people practised open defecation, in 2020
6.2.1b HYGIENE
2.3 billion people
29% of the world's population
lacked a basic handwashing facility with soap and water at home in 2020
6.3.1 WASTEWATER
Globally 44% of household wastewater is not safely treated
6.3.2 WATER QUALITY
The lack of water quality data for over 3 billion people
means that they are at significant risk because the health of their rivers, lakes and groundwater is unknown
6.4.1 WATER-USE EFFICIENCY
Since 2015 water-use efficiency has increased by
10% globally
6.4.2 WATER STRESS
2.3 billion people live in water-stressed countries
of which 733 million live in high and critically water-stressed countries
6.5.1 INTEGRATED WATER MANAGEMENT
107 countries are not on track to have sustainably managed water resources by 2030
Globally, the current rate of progress needs to be doubled
6.5.2 TRANSBOUNDARY COOPERATION
Only 24 countries
reported that all the rivers, lakes and aquifers that they share with their neighbours are covered by operational arrangements for cooperation
6.6.1 ECOSYSTEMS
1/5 of the world's river basins
are experiencing rapid changes in the area covered by surface waters
6.a.1 INTERNATIONAL COOPERATION
Official development assistance (ODA) commitments to the water sector increased
9% from 2015 to 2019, but disbursements showed little change
6.b.1 PARTICIPATION
Only 14 countries out of 109
report having high levels of participation by communities in water and sanitation decision-making

Evolution can be seen in the available data (Table 1 and Figures 1 and 2), but it reflects not only real developments, but also the addition of data for countries not previously included in the indicator calculation. Many countries lack data to compute the indicators, and UN Projects, such as **Water in the World we Want (UN, 2020),** recognize this problem while addressing the challenge of producing critical evidence for water-related policies.

The data, presented here for indicator 6.1.1 as an example[2] (Figures 3 and 4), also show that the average values presented for each indicator have to be taken carefully, as they mask different situations. The vastly distinct realities within the data are clear when comparing present the proportion of the population using safely managed drinking and sanitation services in two regions: Europe/North America and Sub-Saharan Africa (Tables 2 and 3). Engineering solutions have to be tailored to specific situations and therefore average values are of limited use.

[2] Data for the other indicators can be found here: https://www.sdg6data.org/

*Table 1 – values of the indicators used to asses SDGs 6 targets in two reporting periods. *not enough country data were reported to estimate the indicator*

| Indicator | 2017 reporting | 2020 reporting |
|---|---|---|
| % of the world's population using safely managed drinking water services (SDG indicator 6.1.1, 2007-2020) | 71 | 74 |
| % of the world's population use a safely managed sanitation service (SDG indicator 6.2.1a) | 45 | 54 |
| % of the world's population have access to a basic handwashing facility (SDG indicator 6.2.1b, 2014-2020) | 60 | 71 |
| % of the world's household wastewater is safely treated (SDG indicator 6.3.1), 2020) | * | 56 |
| % of the world's monitored water bodies has good ambient water quality (SDG indicator 6.3.2) | * | 72 |
| ratio of dollar value added to the volume of water used at the global level (SDG indicator 6.4.1) | 23$/m3 | 19$/m3 |
| % of the world's renewable water resources is being withdrawn, after taking into account environmental flow requirements (SDG indicator 6.4.2) | 17 | 17 |
| degree of implementation of integrated water resources management (IWRM) at the global level (SDG indicator 6.5.1) | 54 | 54 |
| % of transboundary basin area has an operational arrangement for water cooperation (SDG indicator 6.5.2) | 59 | 58 |
| the change in the extent of water-related ecosystems (SDG indicator 6.6.1))) | * | * |
| global amount of water- and sanitation-related official development assistance received in 2019 (SDG indicator 6.a.1) | 9.3b$ | 9.3b$ |
| Community participation is measured through multiple indicators which are not aggregated into one overall value (SDG 6 indicator 6.b.1) | - | - |

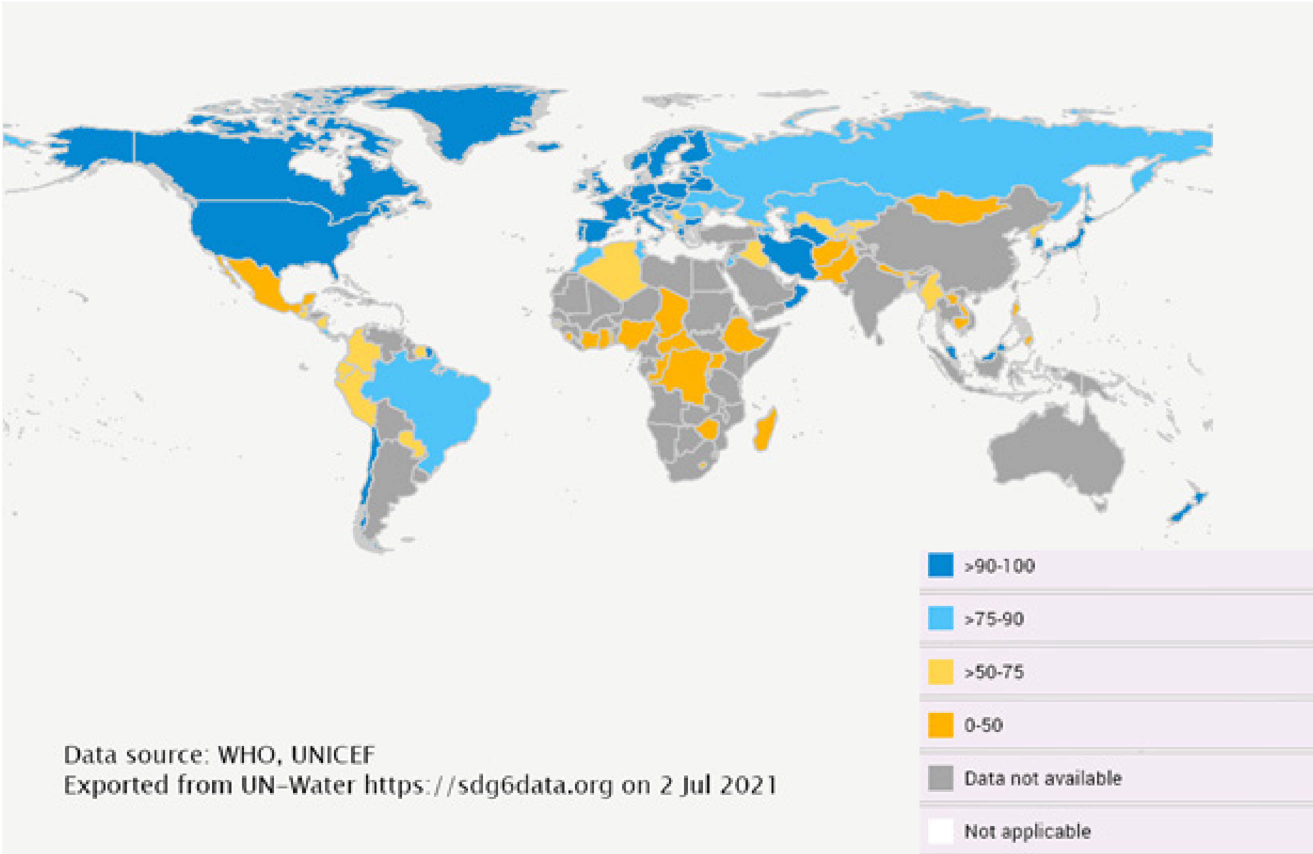
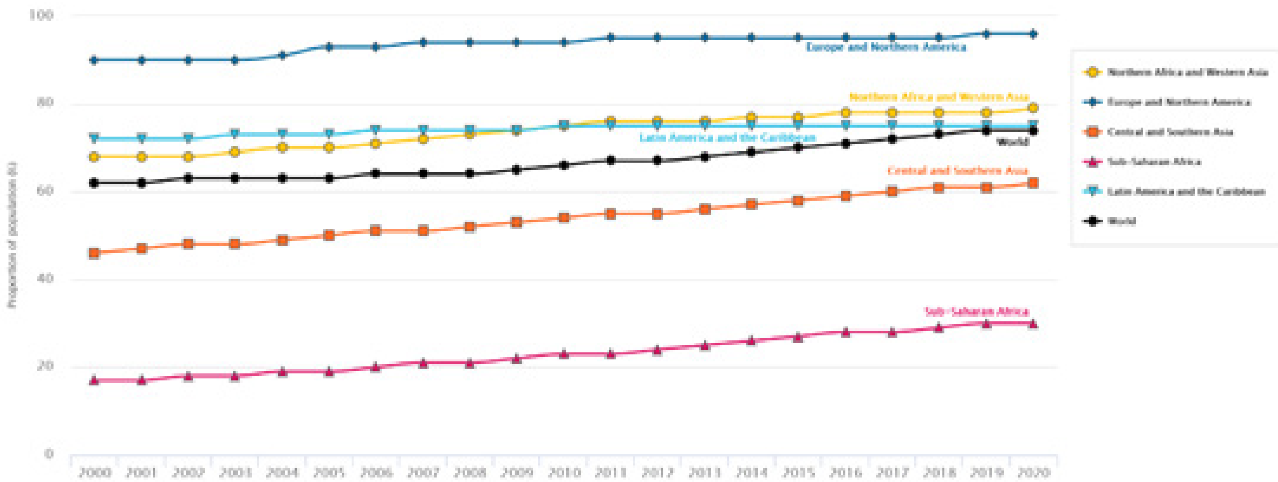



*Figure 1 – Proportion (%) of population using safely managed drinking water service. Downloaded from: https://sdg6data.org/indicator/6.1.1.*




Data source: WHO, UNICEF
Exported from UN-Water https://sdg6data.org on 2 Jul 2021

*Figure 2 – Evolution of the SDG 6.1.1 from 2000 to 2020.*

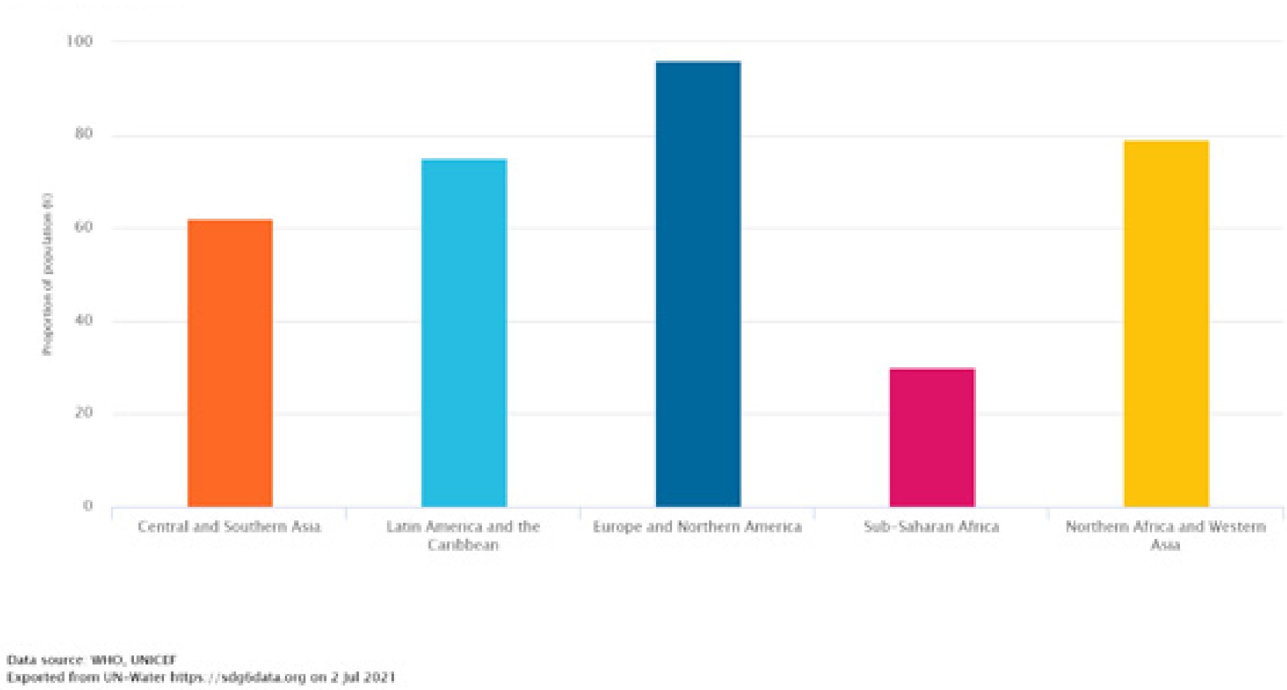



*Figure 3 – Status of SDG 6.1.1 in different regions of the world.*

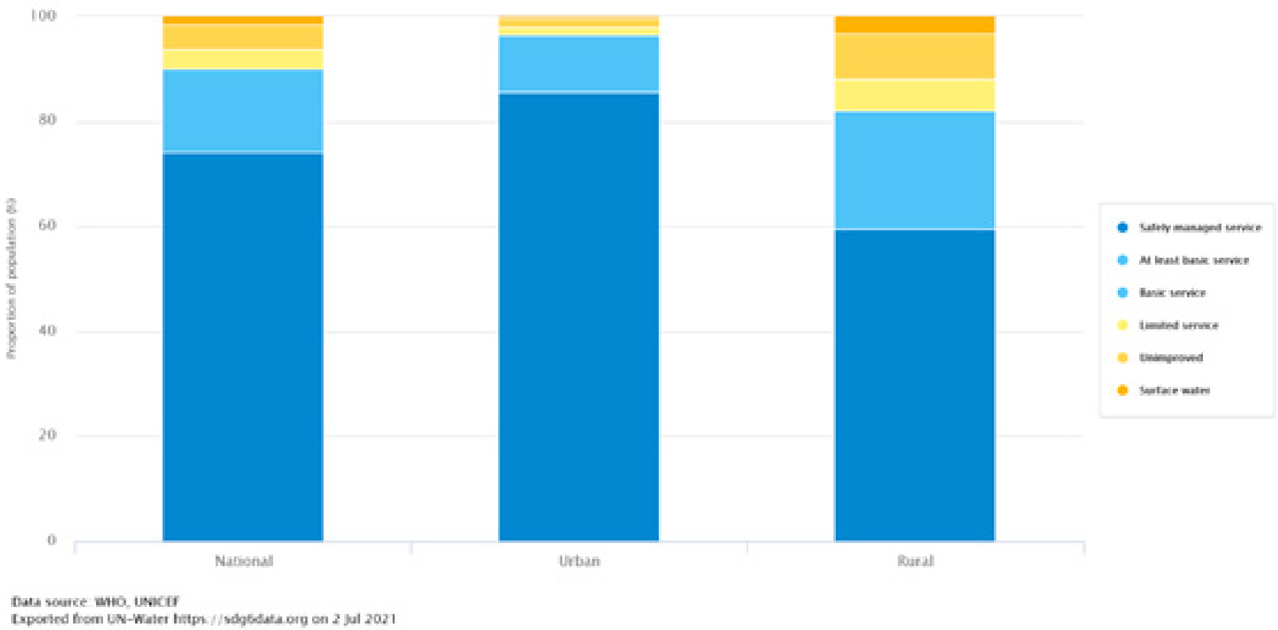


*Figure 4 – Status of SDG 6.1.1 for different components of the indicator.*

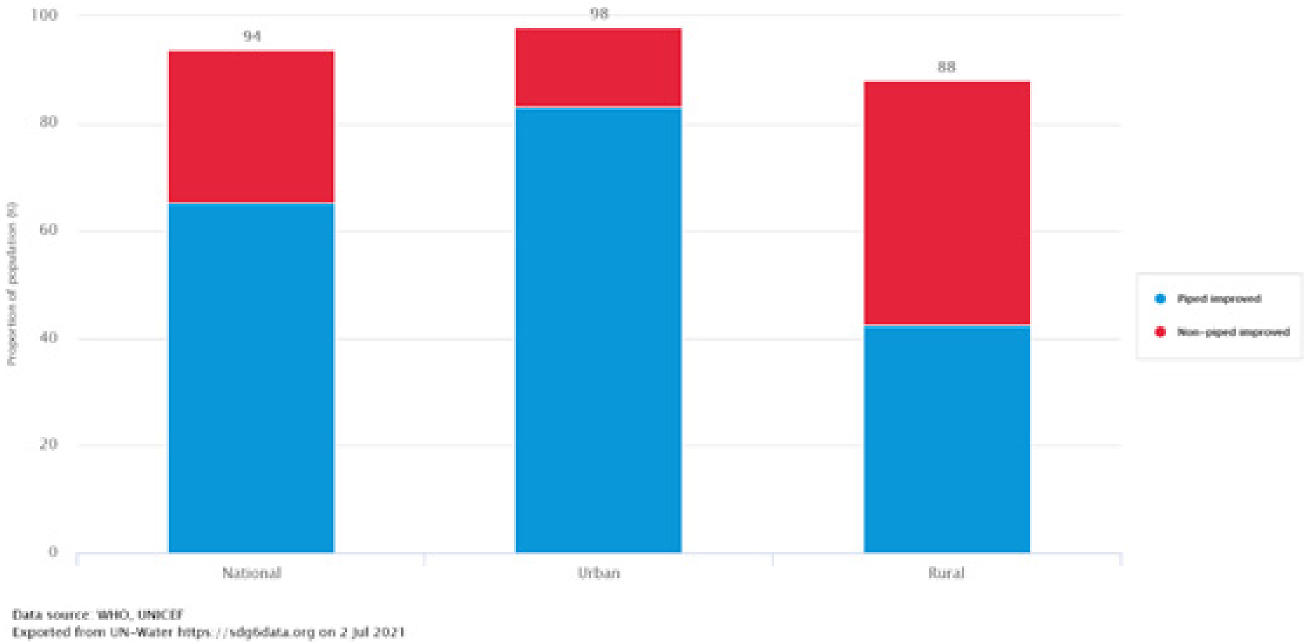



*Table 2 - Proportion (%) of the population in two regions using safely managed drinking water service according to different service levels. Data: https://washdata.org*

| | Proportion of population | |
|---|---|---|
| | Sub-Saharan Africa | Europe and North America |
| Safely managed servisse | 26,9% | 95,3% |
| Limited service | 13,2% | 0,5% |
| Basic servisse | 34,0% | 3,5% |
| Unimproved | 17,6% | 0,6% |
| Surface water | 8,3% | 0,0% |

*Table 3 – Proportion (%) of the population in two regions using safely managed sanitation service according to diferente service levels. Data: https://washdata.org*

| | Proportion of population | |
|---|---|---|
| | Sub-Saharan Africa | Europe and North America |
| Safely managed service | 18,4% | 76,2% |
| Limited service | 18,1% | 0,6% |
| Basic service | 12,3% | 21,3% |
| Unimproved | 31,2% | 1,8% |
| Open defecation | 20,0% | 0,0% |

Despite all data limitations, it is clear that we are still far behind the SDG 6 targets. In fact, the UN has recently recognized that SDG 6 targets are alarmingly off track and developed an acceleration framework (UNWater 2020). The acceleration framework aims to deliver faster results at an increased scale and includes the following five accelerators:

1. **Financing.** Optimized financing is essential to get resources behind country plans.
2. **Data and information.** Data and information targets resources and measures progress.
3. **Capacity development.** A better-skilled workforce improves service levels and increases job creation and retention in the water sector.


4. **Innovation.** New, smart practices and technologies will improve water and sanitation resources management and service delivery.
5. **Governance.** Collaboration across boundaries and sectors will make SDG 6 everyone's business.

# 3 Engineers contribution to SDG6 Goals

## 3.1 initial considerations

This chapter is about the engineer´s contribution to SDG6 goals.

As it was presented in Chapter 2, reliable data are lacking for many countries, in particular for countries with lower levels of material development, where most of the problems are.

Water is an economic, environmental, social and political issue, very much dependent on climatic conditions, on the national wealth and on the public and private institutions responsible for planning, management, and investment.

Water problems are site specific and, to a great extent, country specific.

Engineers have been and will continue to be part of the solution in both developed and developing countries, using appropriate technologies and solutions adaptable to the scale and capacity of local conditions.

Overall, universal access to WASH will not be achieved for a long time in a great number of developing countries at current rates of progress. These countries also experience rapid and often unplanned urbanization which has put a strain on clean water supply and sanitation services. As access to clean safe water and decent sanitation is recognized as a basic human right by the United Nations, there is pressure on local and national authorities to meet their political and social commitments in this regard. Engineering can help explore innovative solutions to deliver water supply and sanitation, combining traditional approaches of large centralized systems with decentralized non-sewered solutions, ranging from more effective design of septic tanks through to waterless toilets.

In order to ensure water security, realize SDG 6 and build resilience to climate change, engineering must provide the necessary knowledge and technology to lead efficient water governance and management.

Water engineering is multidisciplinary and benefits from progress in technological innovation in areas such as microelectronics, nanotechnology, fine chemicals, biotechnology, data acquisition, satellite-based earth observation, hydro-environmental modelling and remote sensing.

Solutions to the complex issues related to clean water have been addressed in a multidisciplinary way by engineers from different disciplines, applying scientific knowledge and providing innovative solutions to global water problems. Historically, civil engineers have played a prominent role in the construction of large infrastructure projects and water resources development. Other engineering disciplines, such as mechanical, chemical, biological, environmental, agricultural, electronic and computer engineering, have also contributed by offering new technological solutions and enhancing options for sustainable water management policies.

In addition to the design of water infrastructures (dams and reservoirs, channels, pipelines, pumping stations, water treatment plants), engineering contributions include the technification of systems, providing them with 'intelligence' that enables better operation and management through research and development, and knowledge transfer (Trevelyan, 2019). Some examples of engineering contributions include:

- supporting water governance with an integrated water resources management approach;
- improving water-use efficiency and reducing losses in municipal distribution networks and industrial and energy cooling processes;
- implementing nature-based solutions in rivers, aquifers and sustainable urban drainage;
- protecting and restoring water-related ecosystems;

- introducing alternative water sources, such as safe wastewater reuse, storm runoff and desalination, which can also relieve water stress; and
- assessing and managing risks of extreme events (floods and droughts), which are natural phenomena that cause major human and economic losses.

Significant progress in water and environmental engineering in recent decades has led to the development of new and more efficient water technologies, such as advanced oxidation, adsorption, reverse osmosis, and nano- and ultra-membrane filtration, which are used in the removal of priority pollutants in advanced water treatment.

Advances in wastewater treatment processes have been made in removing usable substances (e.g. phosphorus and ammonium) and other products for further processing, for example, using organic matter to produce biogas or base chemicals, which can be used in the pharmaceutical industry, and in promoting a circular economy while also preventing the discharge of harmful substances into water resources and the environment.

The Internet of things (IoT), Artificial Intelligence, new data-driven analysis and control algorithms are currently transforming water systems from passive, single-purpose urban infrastructure elements into active and adaptive units making them more efficient, more innovative and more sustainable.

Innovations in engineering disciplines, such as aerospace, satellite technology, electronic and computer engineering, as well as in remote sensing technologies, contribute to identifying trends in the water cycle that are of paramount importance for the comprehensive assessment of quantitative and qualitative water-related climate change impacts.

**BOX 1 - Innovative engineering contributions to global water problems**

Engineering developments offer innovative solutions to global water challenges, provide vital information on sustainable water resources management, support scientific research on new and emerging water issues, and promote science-based decision-making on water topics. Furthermore, engineering advancements can help mitigate and anticipate future water challenges, and contribute to a comprehensive assessment of climate change impacts related to water.

- Advances in chemical engineering and environmental analysis. Contributions to the development of wide-spectrum and high-precision analytical tools, which have brought to light the presence of ever greater types of pollutants in water resources, have made it possible to detect and quantitatively assess new pollutants that were not previously known to be present in the environment. With high-precision and high-sensitivity analytical equipment, it has also become possible to detect pollutants at much lower concentrations than those detectable with low sensitivity conventional techniques that were used in the past.
- Developments in biochemical engineering. Advanced oxidation and adsorption technologies provide solutions for the pre-treatment of specific pollutants such as pharmaceutical residues and chemicals in wastewater from hospitals and industrial facilities prior to discharge to municipal sewers.
- Innovations in environmental engineering. Cutting-edge engineering technologies such as ultrafiltration, nano-filtration and reverse osmosis are used in advanced water and wastewater treatment and have also proven effective for the removal of emerging pollutants from wastewater.
- Advances in remote sensing. Wireless sensors for monitoring water consumption have been developed and are increasingly used to allow for remote water metering. Evolutions in the field of data acquisition have been facilitated by high-speed internet networks and global coverage, as well as cloud computing and the enhancement of virtual storage capabilities. Applications of big data analytics can help to obtain knowledge by processing the collection of continuous streams of water-related information and data. Citizen science and crowdsourcing have the potential to contribute to early warning systems and to provide data for validating flood forecasting models.

**BOX 1 - Innovative engineering contributions to global water problems**

- Innovations in hydro-environmental modelling. Specific and advanced models have been developed for the management of integrated water resources, floods and droughts, precipitation-run off and recharge of aquifers, floodplain estimations, damage previsions, infrastructure resilience, and energy and economic optimizations
- Advancements in aerospace and satellite engineering. Satellite-based Earth observation (EO) can help identify trends in precipitation, evapotranspiration, snow and ice cover/melt, as well as runoff and storage, including groundwater levels. The use of EO imagery coupled with rapid progress in computational engineering has immense potential for water quality monitoring at the basin, national, regional and global levels. The launch of advanced environmental satellites has improved the spatial resolution of satellite images and opened up new frontiers for research on satellite-based water quality monitoring in inland freshwater bodies. Moreover, the open accessibility of most EO satellite images, such as Landsat and Sentinel, further facilitates research and applications, contributing to a better understanding and knowledge of the impacts of climate change and human activities on water resources. Furthermore, the use of EO satellites and drones, makes it possible to monitor water quality and water withdrawals in areas without infrastructure or inaccessibility, especially in developing countries.

## 3.2. Goal 6.1. By 2030, achieve universal and equitable access to safe and accessible drinking water for all

The difficulty in meeting this goal is mostly related to non-serviced and degraded parts of cities and poor rural areas, and the problems are often aggravated by adverse climatic conditions.

Achieving universal access to drinking water was the objective of earlier UN Water Decade Conferences. In the Mar del Plata Conference of 1977, it was stated that "all peoples, whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs." Since then, several broad statements have been produced, namely "serving every man, woman, and child with acceptable drinking water".

The concepts of "safe drinking water" and "for all" became more elastic, depending on affordability, and equality was replaced with equity. Indeed, different standards have been established for people of different levels of income: safely managed, basic, limited, unimproved, and direct use of surface water as it is. Basic service, the second best in the list, means collection of water in less than 30 minutes from home and handwashing with soap on the premises, and it is difficult to accept that it still applies, in 2021, to more than half of the world population and that it may get worse before it gets better.

This is the framework within which engineers are expected to operate. The challenge will be to design and operate the appropriate water infrastructure in each case, taking into consideration affordability to people and economic sustainability of the institutions involved

## JMP LADDERS

| Service level | DRINKING WATER | SANITATION | HYGIENE |
|---|---|---|---|
| SAFELY MANAGED | Drinking water from an improved water source which is located on premises, available when needed and free from faecal and priority chemical contamination | Use of improved facilities which are not shared with other households and where excreta are safely disposed in situ or transported and treated off-site | |
| BASIC | Drinking water from an improved source, provided collection time is not more than 30 minutes for a roundtrip including queuing | Use of improved facilities which are not shared with other households | Availability of a handwashing facility on premises with soap and water |
| LIMITED | Drinking water from an improved source for which collection time exceeds 30 minutes for a roundtrip including queuing | Use of improved facilities shared between two or more households | Availability of a handwashing facility on premises without soap and water |
| UNIMPROVED / NO FACILITY | Drinking water from an unprotected dug well or unprotected spring | Use of pit latrines without a slab or platform, hanging latrines or bucket latrines | NO FACILITY: No handwashing facility on premises |
| SURFACE WATER / OPEN DEFECATION | SURFACE WATER: Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal | OPEN DEFECATION: Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches and other open spaces or with solid waste | |

Note: Improved sources include: piped water, boreholes or tubewells, protected dug wells, protected springs and packaged or delivered water

Note: Improved facilities include: flush/pour flush to piped sewer system, septic tanks or pit latrines; ventilated improved pit latrines, composting toilets or pit latrines with slabs

Note: Handwashing facilities may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing. Soap includes bar soap, liquid soap, powder detergent, and soapy water but does not include ash, soil, sand or other handwashing agents.
Household surveys increasingly include a section on hygiene practices where the surveyor visits the handwashing facility and observes if water and soap are present. Observation of handwashing materials by surveyors represents a more reliable proxy for handwashing behaviour than asking individuals whether they wash their hands. The small number of cases where households refuse to give enumerators permission to observe their facilities are excluded from JMP estimates.

WHO UNICEF JMP

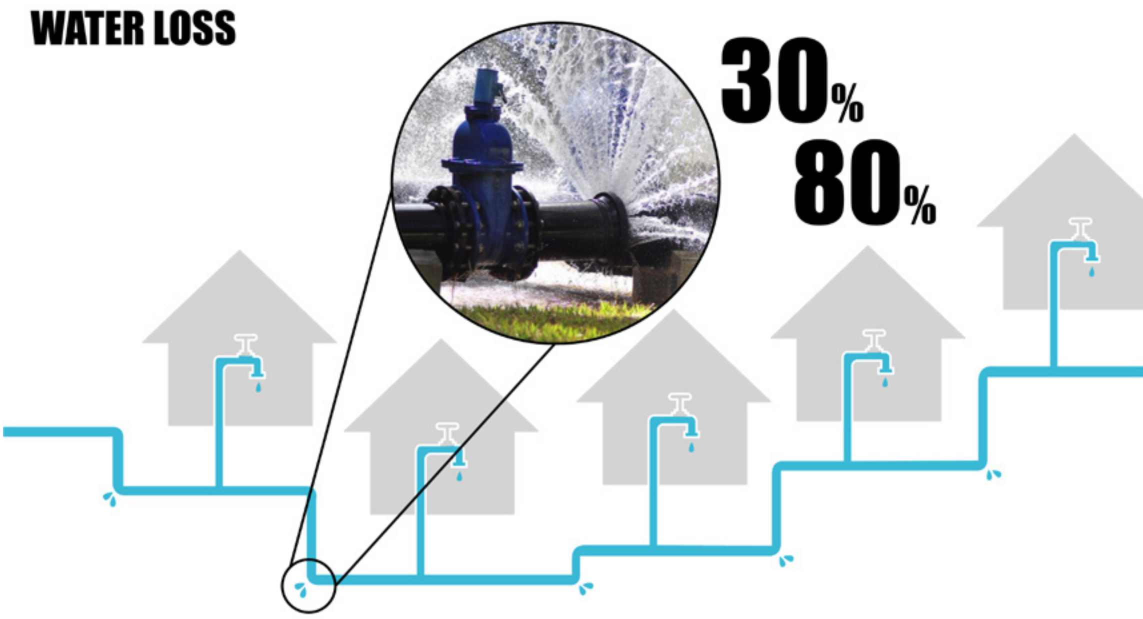
In addition to the development of solutions to the design, expansion, operation and management of conventional water supply systems, using state of the art technologies, engineers will also be involved in finding innovative solutions to old and new problems in water supply, in a context of climate change and poverty.

Among these challenges, the following have been selected:

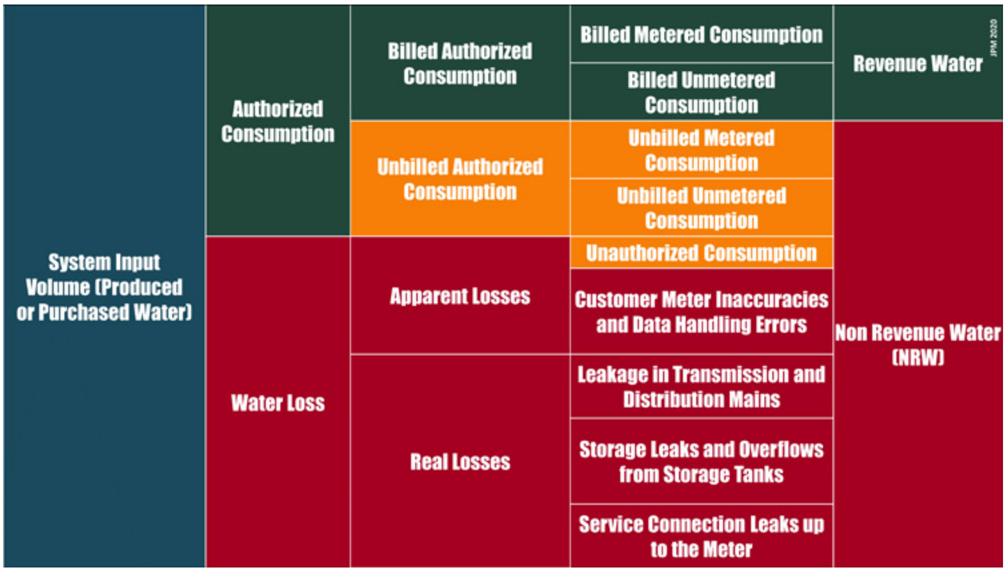
**1. Water loss reduction**

Water loss, a performance indicator of water utilities directly connected to the level of management, is in many cases far above its economic level. In public water supply systems, water loss, technically named as non-revenue water, accounts for significant m3/year and relevant $USD/year. And all around the world, also in developed countries.

This represents a waste of a precious resource, a waste of money and a sub-utilization of expensive infrastructure. Often, new dams, new water treatment plants, new reservoirs and new pipelines are unnecessarily built or the existing infrastructure serves less people than it could serve if the system were managed more efficiently.



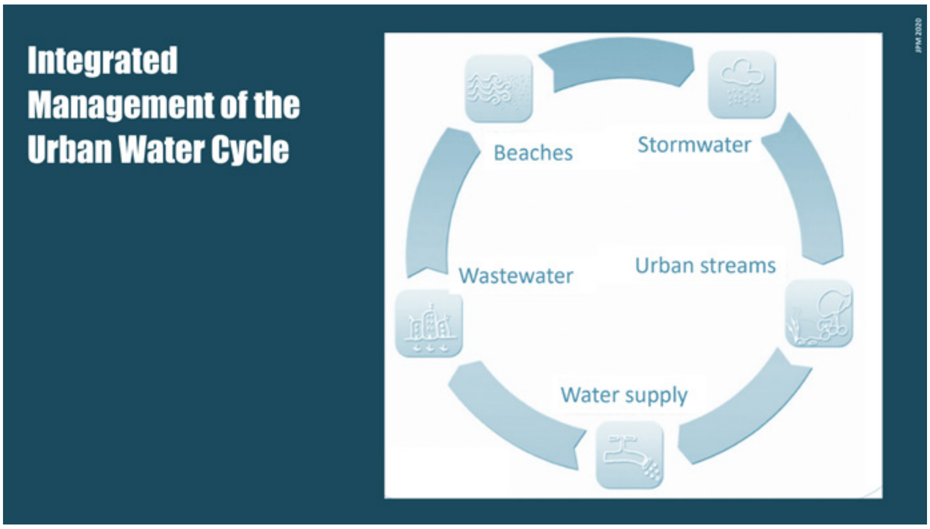
The Water Balance methodology developed by the Water Loss Taskforce of IWA – International Water Association is used all over the world as the standard method to evaluate and characterize water loss. It specifies a commonly accepted terminology and allows for the development of strategies for water loss reduction.




Real losses (water that is physically lost between abstraction and the end user) and apparent or commercial losses (water that reaches the end users but it is not paid for) account for some 30% of the system input volumes in average all over the world. Consider that, the well managed utilities, most of them in developed countries, have values much lower than this, some below 10%, while others, mostly in developing countries, have water losses well over 50%.

High water losses mean wastage of a valuable and scarce resource, but it also means oversized expensive infrastructure, less people served by each system, higher costs, and higher tariffs. This is unacceptable in any case, but it is dramatic in utilities serving people struggling with poverty, as inefficiency leads to higher tariffs, poor quality of service, or both.

Experiences in some cities show that higher levels of effectiveness and cost efficiency are achieved if the urban water cycle is managed by a single organization. The management of water supply and wastewater systems is quite common, but often the storm water system is managed separately. The integration of urban streams in the design of cities and in the daily life of the citizens has many advantages and, on the other hand, the water quality in the beaches depends on the management of the storm water and wastewater systems.




Engineers know very well how to reduce water loss and how to keep it low, but the reasons for it are beyond their technical scope: poor institutional models, poor organizational design, lack of resources and poor management.

However, many engineers are also excellent managers and, specially, excellent managers of change, capable of moving water utilities from bad to good to great in a few years, and this may have an enormous impact on the achievement of SDG6 water supply goals.

**2. Water treatment, reused and desalinated water**

There has been a great evolution in water treatment science and technology, namely in terms of advanced physical, chemical, and biological processes.

Compact plants of different types, capable of treating groundwater, surface water, brackish water and even sea water are offered in the market with capacities ranging from a single house to many thousands of people.

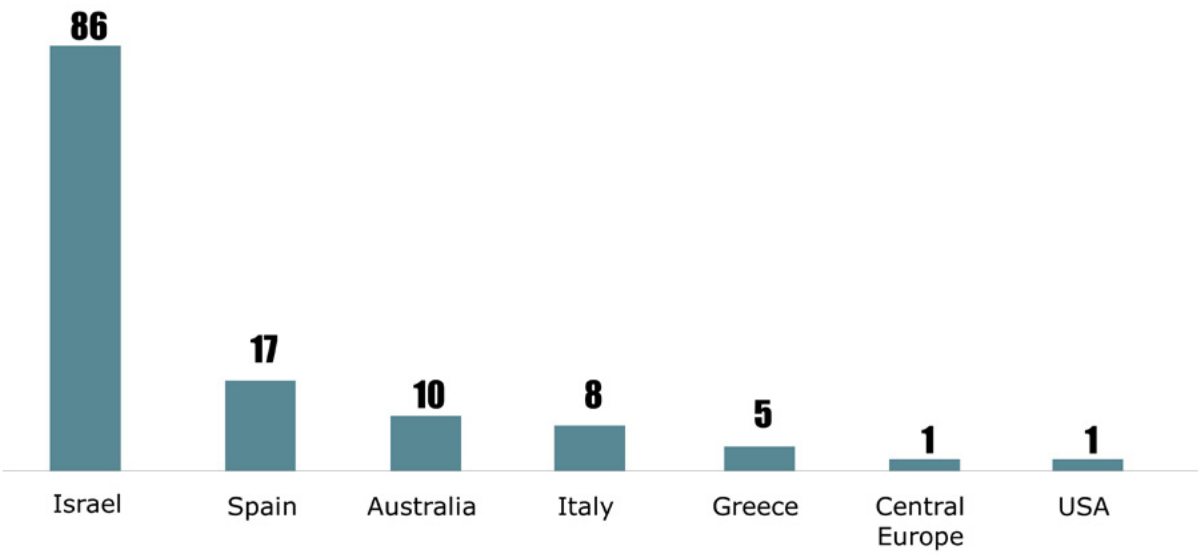
There is an increasing offer of portable, self-contained devices, used to purify water from untreated sources (such as rivers, lakes, and wells) for drinking purposes. These units provide an autonomous supply of drinking water to people without access to clean water supply services, including inhabitants of developing countries and disaster areas, military personnel and campers.

Large water treatment plants, including desalination plants, involve complex technology, require large investments, large infrastructures, and sophisticated contractual formulas to successfully build them. There is a consistent move towards increasing levels of treatment of wastewaters before discharge for environmental reasons.

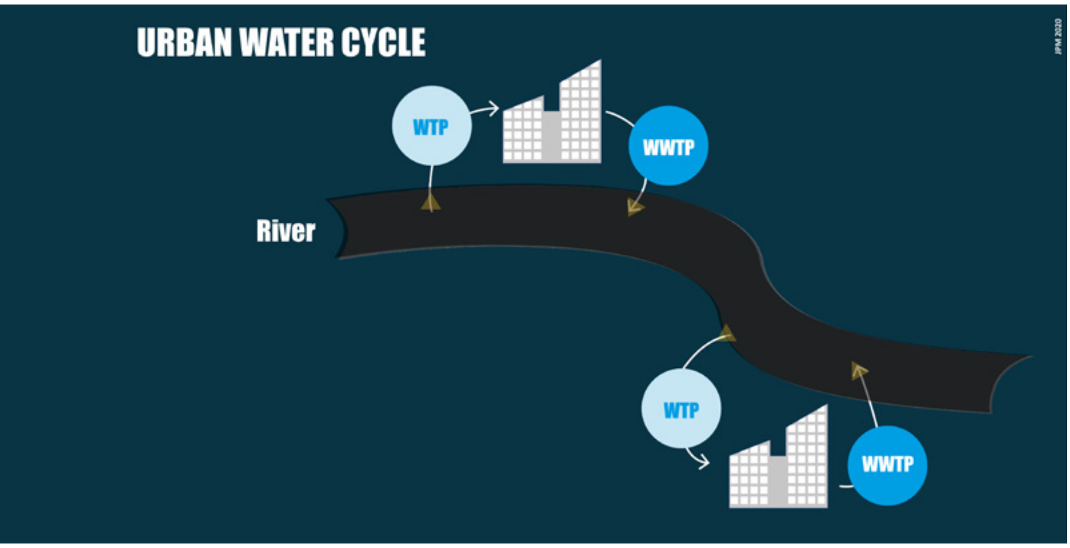
The water abstracted in nature for human consumption inevitably incorporates pollutants that have not been destroyed in the treatment and self-purification processes. Conventional water treatment plants are designed and operated to deal with most of those pollutants, and in fact part of the water they treat has been used before, configuring a de-facto reuse that has been going on for many decades all over the world.

Direct reuse of wastewater is an obvious further step which started in the seventies of last century and of which there are notable examples in spaceships, in Windhoek, Namibia and in Singapore. Moreover, if we reused all the wastewater in cities and in factories to a much greater extent, we would solve two great problems: there wouldn't be shortage of water, a huge advantage in a context of climate change, and there wouldn't be pollution caused by wastewater in rivers, lakes, aquifers and the sea.

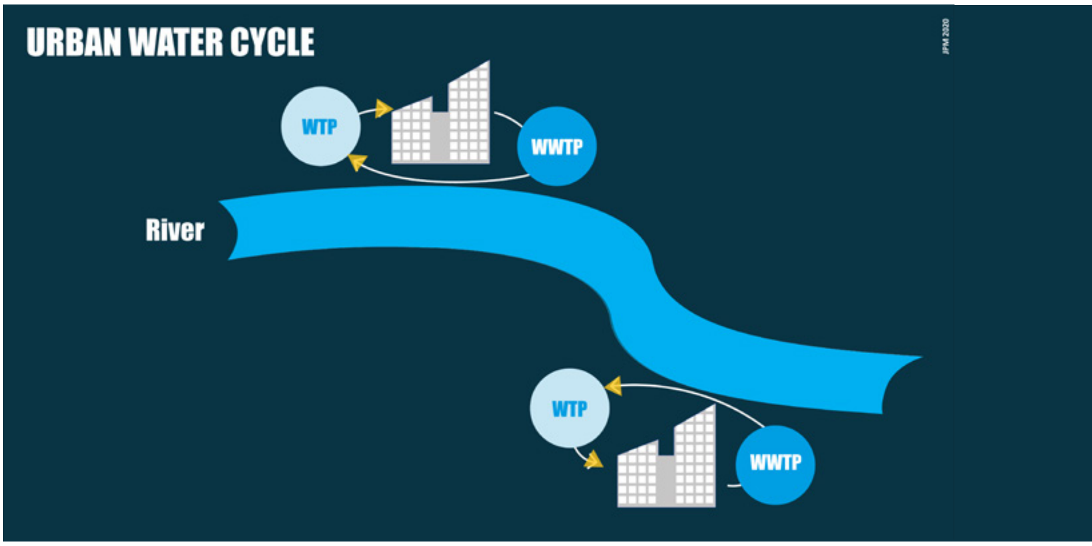
Currently, water reuse in the world is still an exception, and mostly confined to agricultural reuse of urban effluents and very little reuse of industrial effluents within the same factory. Israel and Spain are exceptions to this rule.




In addition to reused water, the use of desalinated water should be considered as an alternative source of freshwater at areas near the coast. There is already technology for this and prices of transforming wastewater and salt water into potable or industrial water are approaching the prices of potable water produced in conventional water treatment plants.




There are already examples of reuse of urban wastewater, treating it to meet potable water quality standards. Public acceptance has not been easy to achieve, it required lengthy processes of communication until finally confidence was established. The COVID-19 pandemic has produced changes in our way of living at a pace that we wouldn't have considered possible. This may also happen in relation to the public acceptance of direct reuse.



With abundant cheaper energy it will be possible to reuse wastewaters and desalinate salt water much more extensively and to pump water for hundreds or even thousands of kilometres inland. In a context of climate change, this may overcome the difficulties to obtain water from natural ecosystems or when artificial reservoirs may no longer transfer water from winter to summer and from wet to dry years due to longer lasting and more severe droughts.

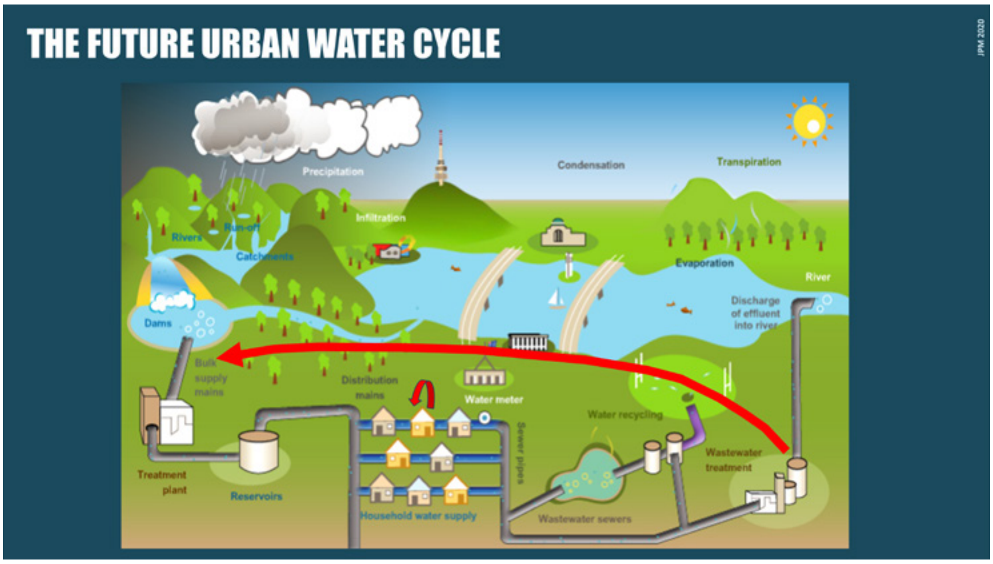
The direct reuse will only be necessary in some situations of scarcity, in cities far from the sea. However, the advantages in terms of the quality of the rivers, lakes, estuaries and sea should also be taken in consideration. In fact, we are currently treating the urban and industrial effluents typically to a secondary/biological level, relying on the self-depuration capacity of the water bodies, but this really leads to an externalization of costs, deteriorating the water quality of recipient water bodies.

The technological problems of direct reuse have been solved, but there are understandable cultural, regulation and legal barriers to overcome before it becomes more widely used in zones where there are no alternative sources, not even the sea.

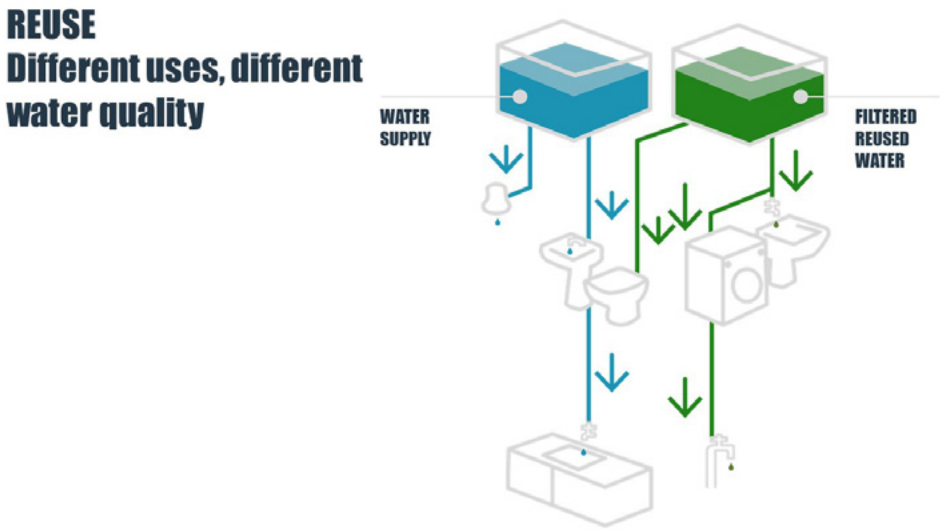
### 3. Individual vs public water supply systems

Long ago, before the advent of cities, individual water supply was the rule. With the growth of cities and the migration from rural areas, public systems for water supply, wastewater, electricity, gas, telephone, and internet, became the obvious solution, with significant economies of scale.

The situation changed drastically with the progress of decentralized electricity production (prosumers), the electrification of the economy (to avoid CO2 production), the mobile phones and the wireless Internet. Following these trends, it will also be possible to increase the reuse of water at quarter, building or even house levels.



We seldom use rainwater at our houses and the rule is supplying potable water for all purposes. We typically use over 100 litres per person of potable water a day for drinking, preparing food, fluxing the toilets and watering the garden, but only a minor proportion needs to be potable. Consequently, there may be a change in new cities towards the installation of two public water supply networks, or to provide water of a near potable quality and install water purifiers at each house to produce the comparatively small amount of potable water we require daily.




As far as water is concerned, there are already solutions to reuse greywaters and sewage at each house, with or without incineration dry toilets. It is possible to store rainwater and there are emerging solutions to abstract water from the air.

It is still not clear what the situation will be in a few decades, as far as the sizing of public water supply and wastewater systems are concerned.

In the short run, it will be business as usual, and engineers are more than ready for it, but they are also involved in research and development of the ongoing technological processes of change which may lead to a progressive decentralization of water supply and sanitation.

This decentralization will solve the problem of the impossibility of physically building and financing conventional sewerage systems; the local treatment and reuse of greywaters will avoid pollution and will reduce drastically the per capita consumption of the water supply systems of the future and, therefore, the need for expansion of existing infrastructure.

## 3.3. Goal 6.2. By 2030, obtain access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and vulnerable people

The objective of target 6.2 is to ensure universal access to safely managed sanitation services, eliminating open defecation and moving towards a toilet and a handwashing facility with soap and water at every household.

Engineers will continue to design, build, operate and manage conventional wastewater systems and to participate in the development of new collection, treatment, and reuse technologies.

They will also contribute to the design of new types of latrines, including dry toilets, and to the development and management of new types of public wastewater collection, treatment and reuse systems, which should include the correct maintenance of the individual systems to avoid health problems and pollution due to the disposal of untreated excreta in aquifers and rivers, which would inevitably happen otherwise, if these were left to individual responsibility.

## 3.4. GOAL 6.3. By 2030, improve water quality by reducing pollution, eliminating waste and minimizing the release of chemicals and hazardous materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

More than half of the freshwater withdrawals are released worldwide to the environment as wastewater, over 80% untreated. These global figures are averages: indeed, what happens is that in some countries there is almost 100% treatment and in others there is almost 0%, aggravating the existing inequalities.

This target requires halving the proportion of untreated wastewater in 2030, which is particularly difficult because it must be achieved mostly in developing countries. Climate change and population growth will exacerbate the difficulties.

History of the past decades shows that trying to solve this problem with conventional urban sewerage systems is an impossible task. There are no conditions to implement this type of systems in most of the informal urban settlements, as there is no space in the narrow space between the houses, no conditions to maintain sewage pumping stations and no wastewater treatment plants, almost no public financing, and no affordability or willingness to pay.

A toilet at each premise makes a huge difference in terms of public health, privacy, safety for woman and children, pollution, and dignity: there are already low-cost affordable technical solutions, full-scale examples of providing the providing and maintaining the toilets as a local service, and of financing it through microcredit.

Target 6.3 links wastewater treatment and water quality. By reducing the proportion of untreated wastewater, the target aims to reduce pollution, eliminate dumping and minimizing the release of hazardous chemicals and materials in the environment. It also aims to substantially increase recycling and safe reuse globally.

The main sources of pollution comprise point sources (wastewater from households, commercial establishments and industries) and non-point sources (such as run-off from urban and agricultural land), that require different approaches to be solved. While in countries with good levels of wastewater treatment plants diffuse pollution, namely from agriculture, can be dominant, in many developing regions point sources can be determinant of the quality of freshwater bodies. The approaches to reduce or eliminate these pollution sources should be tailored to the different type of pollution source (i.e. point or diffuse).

This goal also incorporates water recycling, thus contributing to SDG target 6.4 on reducing freshwater withdrawals, improving water use efficiency and reducing the number of people suffering from water scarcity.

Reaching this goal and related targets will require the participation of engineers for all aspects of the problem-solution design chain, including the assessment of water quality. More specifically, it can encompass the design and implementation of effective water quality monitoring programs, the development of innovative methods to assess water quality, including ecological elements, the design and implementation of reuse techniques, including if appropriate direct reuse, the design and construction of adequately scaled wastewater treatment plants (WWTP), modernization of wastewater treatment plants, and the implementation of nature-based solutions (e.g. constructed wetlands and ponds).

## 3.5. GOAL 6.4. By 2030, substantially increase water use efficiency in all sectors and ensure sustainable withdrawal and supply of fresh water to combat water scarcity and substantially reduce the number of people suffering from water scarcity

This target aims at increasing water use efficiency to address water scarcity. It encompasses all sectors and is assessed with two indicators: 6.4.1. Change in efficiency of water use over time and 6.4.2. Water stress level (withdrawal of fresh water as a proportion of available fresh water resources).

According to available data, 17 % of the world's renewable water resources are being withdrawn, after taking into account environmental flow requirements, but this proportion is much higher at dryer areas.

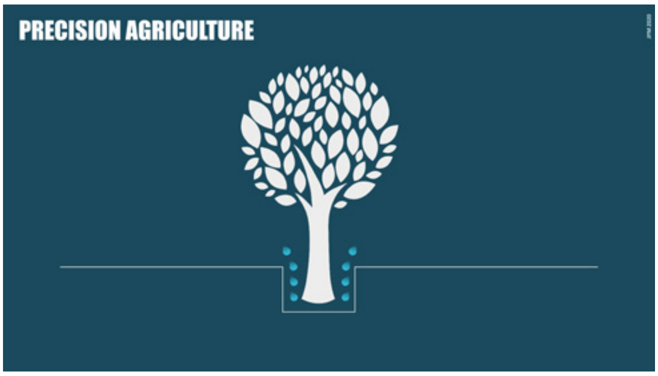
In order to guarantee enough freshwater to produce the necessary food for the growing and higher income population, and to produce and distribute the necessary goods and services, while maintaining healthy ecosystems, it will be necessary to efficiently use the available freshwater resources, pursuing objectives such as "more crop per drop", "more jobs per drop", "better environment per drop" and "improved nutrition per drop".

Notwithstanding, efforts made so far in pursuit of these objectives have not been enough to guarantee the satisfaction of freshwater needs for people and ecosystems, with many examples of inefficient use remaining, only possible due to the low water prices.

Reaching this target will require extensive engineering contributions related with increase use efficiency in urban water supply systems, but also in the way agriculture use this vital resource. Agriculture is by far the largest water user and therefore, as far as saving fresh water resources is concerned, it is where efficiency leads to higher savings.

Reducing losses in older irrigation systems and implementing advanced techniques in irrigation, including precision agriculture, are likely at the forefront at the techniques to be implemented in agriculture, in addition to the use of plant varieties more efficient in the use of water.

Nevertheless, with abundant, less expensive energy, it is possible to pump water from longer distances and even to develop agriculture in desertic regions, with desalinated water.





There are also great opportunities to save water in industries in terms of cubic meters per unit of product and closing internal water circuits. These savings are not always materialized because of the legislation is based on the use of the Best Available Technologies, limited to economical and technical viable conditions and advantages (including environmental impacts) balanced against costs.

In industry, but specially in agriculture, reuse can reduce significantly the abstraction of fresh water, but the possibility of abstracting fresh water at a very low costs or for free in practice eliminates the economic interests of reuse, except in cases of very severe scarcity, when rationing measures are imposed.

Important actions could be taken to reduce losses in urban water supply systems, as even in developed regions losses can be quite high. Reducing water losses in municipal distribution networks has a double advantage: it reduces the abstraction of water resources, but perhaps more significant than this considering that human consumption is far less than agriculture and industries in the majority of cases, it allows for serving more people with the same infrastructure or avoids building larger pipes, water treatment plants and storage water tanks.

In some areas, scarcity will also require the implementation of demand management policies, with prioritization of diferente uses, namely within the framework of Integrated Water Resources Management (IWRM).

As for other goals, the reuse of freshwater, including for potable purposes, will clearly contribute to increase the efficiency in the way we use the freshwater abstracted from rivers, lakes, reservoirs and aquifers. Consequently, increases in water reuse will allow larger quantities of water to remain in the natural systems, contributing to maintaining and restoring ecosystem health.

In addition to reused freshwater, other water sources could be used to reduce the pressure upon natural freshwater resources and to contribute to reduce scarcity, where needed. In dry areas near the coast, desalination can be considered as an alternative way to provide freshwater. For example, in Israel, desalination and the infrastructure and organization of reuse make it possible to obtain water from “new origins” at less than 0.5 $USD per cubic meter.

## 3.6. GOAL 6.5. By 2030, implement integrated water resources management at all levels, including through cross-border cooperation, as appropriate

In some densely occupied regions, it rains almost every day, and there is abundance of water, but these cases are exceptional. When and where there is scarcity, it is necessary to allocate the available water. This can be done through adequate water governance, which includes planning, management, water pricing, permits, seldom through the trading of water rights and often informally, on a first come first served basis, but this is prone to originate conflicts between users and also between countries sharing international river basins.

Storage helps to transfer water from wet months to dry months and from wet hydrological years to dry ones. It is also possible to transfer water between river basins. Solutions of this type, artificializing the rivers and hydrological regimes to a great extent, have been followed extensively in the past in many countries, usually following supply driven water policies.

Water planning and management at the river basin scale basin, supporting water governance, continues to be a proven approach. In fact, although IWRM remains a debated concept, it provides the framework for addressing different demands/users and pressures on freshwater resources at the river-basin level, targeting sustainable water management and conflict mitigation.

IWRM should provide the basis for the management of transboundary river basins. Cross border cooperation is necessary in international river basins and there are many examples of bilateral and multilateral international agreements and abundant international legislation on the subject. Again, this should contribute to reduce conflict in the relatioships between users and countries/regions.

**BOX 2 - The "Convention on Cooperation for the Protection and Sustainable Water Use of the Luso-Spanish Hydrographic Basins**

Spain and Portugal share five main river basins, including some of the largest basins in the Iberian Peninsula. (Duero/Douro, Tajo/Tejo, and Guadiana). In general, Spanish territory is upstream and around 70% of the annual flow of these rivers is generated in Spain. Extreme inter and intra-annual variations in rainfall – from season to season and year to year – are typical in the region, particularly in the drier South.

The last agreement between Portugal and Spain about shared water resources was signed in Albufeira (Portugal) in 1998 and entered into force in 2000. The "Convention on Cooperation for the Protection and Sustainable Water Use of the Luso-Spanish Hydrographic Basins", in short the "Albufeira Convention (AC)" is based on the International and European legal frame on shared basins.

As its name implies, the purpose of the AC is to cooperate, protect and making a sustainable use of the water resources of the shared basins. The AC deals primarily with water quantity, establishing flow regimes that guarantee minimum flows that must enter the Portuguese part of each basin, coming from Spain. Flows are established for fixed river cross sections and may include annual, quartely, weekly and daily water volumes. The Convention also establishes "times of exception", i.e. periods during which, because of water scarcity, the flow regimes established may not be applied.

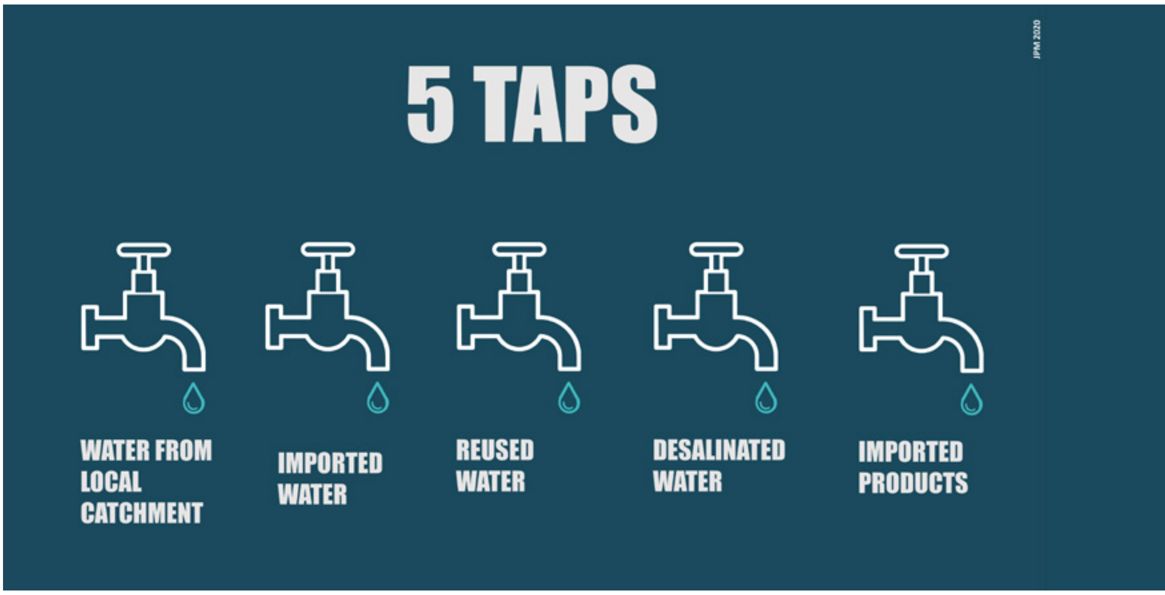
The AC instituted two cooperation bodies: one, aimed at political interventions, and a technical Commission. The political body meets when the two countries decide, acting as an appellate body to agree on certain issues not resolved within the technical Commission.

As regulations are often specific to each sector, policy articulation is crucial for good results in IWRM. In The European Union, the Water Framework Directive has introduced an integrated approach to the management of water basins within its member states, whereas other regions of the world also use IWRM for water management.

Overall, IWRM could be considered a framework linking all Goal 6 indicators, including those on water use efficiency, water supply, sanitation, wastewater treatment, water quality and freshwater ecosystems, and water and sanitation.

Population and GDP have been increasing in many regions and countries of the world, and the water consumption has increased at a faster rate to support such growth, creating or exacerbating water use conflicts. Fortunately, there are new sources of water that could make water governance easier, reducing scarcity and conflicts: reuse and desalination.

Following Singapore's innovative description of the 4 national taps (rain water, directly imported water, reused water, desalinated water) and including the indirect importation of water as a fifth tap, the planning and management of water resources of any region or country may include these "five taps" in the future: currently, we use mainly the first two taps, rain water and directly imported water from other regions and, to a great extent, indirect import of water through food and manufactured products, e.g. for each kilogram of beef, we really indirectly import 15 500 liters of water.




The costs of desalination and reuse of urban wastewaters up to potability standards is approximately the same, currently less than 0.5 $USD a cubic meter, as they can be achieved through similar membrane technologies (reuse can also be carried out biologically and incineration by distillation).

This cost, which is likely to decrease substantially in the future, due to more efficient reverse and direct osmosis technologies and to cheaper solar energy (eventually, later, safe nuclear energy), is already comparable to the production of treated water using conventional processes in some green field situations, where fresh water sources are far away from the users.

Of course, there is a great difference between the costs of desalination (and direct reuse wastewater treatment plants) operating continuously at their nominal capacity and the costs of using them occasionally when the freshwater sources are not sufficient. In the first case, it is possible to use Design-Build-Finance-Operate (DBFO) contracts, paid through the water tariffs, without public financing, as it is the case in the Middle East and Singapore for instance.

There are already high value agricultural crops and industrial products that are competitive using desalinated water, but this is still not the case with the majority of the agriculture and industrial products.

The establishment of water prices is a politically and economically very sensitive issue: it would be easy if the agricultural and some industrial sectors followed market rules, but this is not the case almost everywhere in the world, as there is a tradition of subsidizing food production, rural development and rural employment.

Besides participating in the construction of the legal framework needed for successfull IWRM, engineers are involved in many aspects of IWRM, beginning with the gathering of hydrological and water quality data, and the design, implementation and management of water infrastructures, such as dams, channels, pipelines and water treatment plants, but also while planning, designing and executing river restoration projects, nature based solutions for wastewater treatment and fish passes. The elaboration of water planning also requires the development and use of analytical tools for modeling the complex people-environment-water systems.

Engineers also participate in the innovation and development of technologies and equipment, and technically support political negotiations on national and international water issues.

Despite its inherent values, there is a need to make IWRM more effective towards the achivement of SDG 6. The amount and quality of data should be checked, as the quality of the management plan will rely on them. In particular, the evaluation of hydrological data, to asses present and future availability, should explicitly incorporate climate change influences and their uncertainty. Governance models should also be improved, for example by implementing the **OECD principles on water governance.**

Other particular aspects requiring improvement would include the determination and implementation of effective environmental flows, and flood and drought risk management. Moreover, to achieve SDG 6, there is a need to not consider IWRM as an end in itself, therefore increasing the focus on its implementation and operationalisation, including the need for financing.

## 3.7. GOAL 6.6. By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

This goal is pivotal to reach SDG 6, as the services provided by water-related ecosystems include, not only the provision of good quality water, but also the ability to naturally purify water, e.g. by reducing the levels of nutrients.

In addition, achieving the other SGD 6 targets will almost directly have a positive influence on ecosystems, since pressures are reduced. For example, all increases in water use efficiency and water reuse will decrease the abstraction of water from ecosystems and reduce the amount of wastewater produced, impacting positively on the health of aquatic ecosystems.

The protection and restoration of water-related ecosystems (such as vegetated wetlands, rivers, lakes and reservoirs) requires the analysis of options with complex analytical models, incorporating hydrological, biological and sociological data. Within the joint analysis of different knowledge fields, new disciplines are emerging, such as ecohydraulics. The implementation of such models requires good quality data, including data on the ecological quality of the ecosystems.

It is important to set clear objectives for restoration actions, whether it aims renaturalization or some pre-accepted level of degradation, if renaturalization is too costly or impossible to attain due to existing human uses. The concepts of good ecological status and gool ecological potential, as described in the European

Water Framework Directive could be used as a theoretical model for establishing attainable goals.

Restoration techniques for water-related ecosystems are continuously improving, despite the need to quantitatively assess the efficacy and the cost-benefit of most restoration projects. Several guides exist with the description of measures to improve aquatic habitats (including the provision of environmental flows), to reduce nutrient levels, to mitigate barrier effect of dams and weirs, among others. This information is often region/site specific, and should be adapted for particular river basins and regions.

**BOX 3 - The 2000 Water Framework Directive**

Recognizing that we all need cleaner rivers and lakes, groundwater and bathing waters, water protection has been one of the priorities of the EU. After previous legislation (e.g. with quality standards set for rivers and lakes used for drinking water abstraction in 1975 and with binding quality targets set for drinking water in 1980), a new European Water policy was envisaged with the 2000 Water Framework Directive (WFD).

The WFD expands the scope of water protection to all waters, aims at achieving "good status" at all water bodies by a set deadline, establishes water planning and management based on river basins (the natural geographical and hydrological unit), considers a "combined approach" of emission limit values and quality standards for pollutants, includes water pricing and get the citizens involved more closely.

There are a number of objectives in respect of which the quality of surface waters is protected according to the WFD. The key ones are general protection of the aquatic ecology, specific protection of unique and valuable habitats, protection of drinking water resources, and protection of bathing water. All these objectives are integrated for each river basin. The last three apply only to specific bodies of water, but ecological protection must apply to all surface waters. For this reason, a general requirement for ecological protection, and a general minimum chemical standard, was introduced to cover all surface waters. The status of a particular surface water body is obtained by combining the "ecological status" and the "chemical status".

**BOX 3 - The 2000 Water Framework Directive**

Groundwater bodies are also classified according to their status, by including both the "chemical status" and the "quantitative status". Quantity is important for groundwater. There is only a certain amount of recharge into a groundwater each year, and of this recharge, some is needed to support connected ecosystems. For good management, only that portion of the overall recharge not needed by the ecology can be abstracted. Larger abstractions compromise the quantitative status.

Particularly innovative in the WFD was the explicit consideration of the ecological status of surface waters, as defined in its Annex V, i.e. the quality of the biological community, the hydrological characteristics and the chemical characteristics. However, as no absolute standards for biological quality can be set which apply across the UE, because of ecological variability, the controls are specified as allowing only a slight departure from the biological community which would be expected in conditions of minimal anthropogenic impact. A set of procedures for identifying that point for a given water body, and establishing particular chemical or hydromorphological standards to achieve it, is provided in the WFD, together with a system for ensuring that each Member State interprets the procedure in a consistent way.

For each river basin district a "river basin management plan" needs to be established and updated every six years. The plan is a detailed account of how the objectives set for the river basin (ecological status, quantitative status, chemical status and protected area objectives) are to be reached within the timescale required.

The plan will include the river basin's characteristics, a review of the impact of human activity on the status of waters in the basin, estimation of the effect of existing legislation and the remaining "gap" to meeting these objectives; and a set of measures designed to fill the gap. One additional component is that an economic analysis of water use within the river basin must be carried out. This is to enable there to be a rational discussion on the cost-effectiveness of the various possible measures, Public participation take place during the making of the plan.

The need to conserve adequate supplies of a resource for which demand is continuously increasing is also one of the drivers behind what is one of the Directive's most important innovations - the introduction of pricing. Adequate water pricing acts as an incentive for the sustainable use of water resources and thus should help to achieve the environmental objectives under the Directive.

## 3.8. GOAL 6.A. By 2030, expand international cooperation and support for capacity-building in developing countries in activities and programs related to water and sanitation, including abstraction, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

Over 80 percent of participating countries reported insufficient finance to meet national WASH targets. Stronger domestic financial engagement and better use of existing resources will be required to achieve the goal of leaving no one behind. Commitments of Official Development Assistance (ODA) to the water sector dropped by 9 per cent in 2018 from the previous year, compared with a 38 per cent increase from 2016 to 2017. Commitments to water and sanitation continued to increase, but at 3 per cent from 2017 to 2018, compared with 19 per cent the previous year. Increasing donor commitments to the water sector remains crucial in sustaining progress towards Goal 6 (UNSD, 2020).

Thus, engineers have an important role in identifying zones of opportunity and monitoring progress, namely within the following topics.

**1. International cooperation**

“Leave no one behind” is the motto of the 2030 Agenda, and a clear sign that we are in fact committed to ensuring that everyone counts in promoting global development. For this, international cooperation is essential to ensure that inequalities between the richest and most vulnerable countries are reduced. Engineering plays an important role in creating solutions adapted to each reality, as well as in its implementation.

**2. Support for capacity building in developing countries**

Needs are greatest in developing countries, calling for an increased mobilization of domestic funds, but also a significant scaling-up of external support. Capacity-building includes strengthening the skills, competencies and abilities in developing countries in regard to water governance and management.

In this sense, without diminishing the importance of good governance and financing which are essential for reaching these targets, it is important to recognize that engineering makes an equally valuable contribution. Engineers play a crucial role in understanding both the energy and water field and are needed to help close the gap between finance and implementation.

## 3.8. GOAL 6.B. Support and strengthen the participation of local communities in improving water and sanitation management

Stakeholder participation is essential to ensure the sustainability of water and sanitation management options over time, e.g. the choice of appropriate solutions for a given social and economic context, and the full understanding of the impacts of a certain development decision.

The participation of local communities in water and sanitation planning and management is essential for ensuring that the needs of all people are being met and that adequate solutions are being planned. The involvement of relevant stakeholders is further necessary to ensure that the technical and administrative solutions decided upon are suitable for specific socioeconomic contexts.

Engineers also play an important role in sharing knowledge with stakeholders, which will be instrumental in helping countries create, strengthen and maintain the systems needed for permanent water and sanitation services.

# 4 Technologies

In the present Chapter, some of the technologies used and in development for future use in the water sector are briefly presented. It is expected that these technologies can contribute decisively to achieve SDG 6. The technologies presented intend to give a general overview of some of the several technologies available.

## 4.1. Fog Harp

Fog harvesting consists of catching the microscopic droplets of water suspended in the wind that make up fog.

Fog Harp aims to develop a full-scale model to test a fog collecting technology. It is a passive, durable, and effective method of water collection, consisting of a vertical array of 700 wires and is based on experimental results. These vertical wires shed tiny water droplets effectively (Network 2020b).

## 4.2. Water management for the South African coal producer

A study in South Africa has shown that effective removal of solids from wastewater can be achieved through a single step process.

It consists of a hydraulic filter press selected to dehydrate the solids, dry and press them in the form of a briquette for transport to final customers. The filtrate, minus the extracted solids, was directed to the evaporation dam before returning to the site processes through a mixing line.

The solution's effectiveness was proven during a two-week trial, which achieved a reduction in solid waste from about 2900 mg/l to just 84 mg/l (Schifter 2020).

## 4.3. Using technology to help manage groundwater

In the Australian city of Dubbo, methods of rapid soil moisture mapping are used and the distribution of groundwater uses the propagation of electric current. The flow of electrical current in the soil is strongly controlled by groundwater, whether saturated, as in boreholes or unsaturated, including root zones. This makes it useful for mapping a large range of depths, from decimeters to tens of meters deep (Research 2020).

## 4.4. Solar technology to produce clean drinking water

The traditional still is little more than a black-bottomed vessel filled with water and topped with clear glass or plastic. The black bottom absorbs sunlight, heating water so that it evaporates and leaves the contaminants behind. The water vapor then condenses on the clear covering and trickles into a collector.

But the output is low because the sun's rays must heat the entire volume of water before evaporation begins. The average person requires about 3 liters of water a day for drinking. Providing enough drinking water for a small family requires a still around 5 square meters in size.

Guihua Yu, a materials scientist at the University of Texas in Austin, and colleagues, fashioned a gellike sponge of two polymers—one a water-binding polymer called polyvinyl alcohol (PVA), the other a light absorber called polypyrrole (PPy)—which they then placed atop the water's surface in a solar still.

Inside the gel, a layer of water molecules bonded tightly to the PVA, each forming multiple chemical links known as hydrogen bonds. But with so much of their bonding ability tied up with the PVA, the bound water molecules bind only loosely to other nearby water molecules, creating what Yu calls "intermediate water." Because intermediate water molecules share fewer bonds with their neighbours, they evaporate more readily than regular water (Service 2019).

## 4.5. Zero Mass Water

Zero Mass Water's Source Hydropanels require no electrical input, pipes, or public utility infrastructure. It is a way of using the resources that are already in abundance around us — the water that exists in our air.

Source Hydropanels function by first adsorbing water vapor from the air onto a hygroscopic material. The efficient application of solar energy causes the water vapor to respire from the materials inside the Hydropanel, raising the relative humidity to a passively condensing vapor. As the hygroscopic materials only attract water molecules, the liquid water produced is pure, not unlike distilled.

## 4.6 More accurate assessments of when farmers should irrigate and how much

A new sensor technology developed at Cornell University connects to a tree or grapevine to read the potential of stem water in real time, replacing weekly pressure chamber measurements to guide irrigation management (Takahashi 2020).

## 4.7. Material for capacitive desalination

A material being developed for the automotive industry could be repurposed for capacitive desalination, making the process up to 40 times faster and less energy intensive.

This is the claim of Guoliang "Greg" Liu, an assistant professor in the Department of Chemistry at Virginia Tech who has conducted research into the design and synthesis of porous carbon fibres. The material is composed of long, fibrous strands of carbon with uniform mesopores of approximately 10nm.

Capacitive desalination using porous carbon fibres requires much less energy for treating water with low salinity (engineer 2020).

## 4.8. Innovative fish passes

Dams and weirs are obstacles to fish movement but their impact can be mitigated by the use of adequate fish passes. Fish passes can include different types and are site specific, according to the height of the barrier, the fluvial habitats and the fish species present. Increase knowledge allow presently the design of increasingly effective fish passes, targeting several species and not only the upstream, but also the downstream displacements. The maintenance of ecological continuity is often a major aspect in restoring degraded fluvial ecosystems (University of New South Wales, 2020).

# 5 Case Studies and Best Practices

In this Chapter several case studies and best practices that can contribute to achieve SDG 6 are presented, particular within the aim of the goals. The best cases presented expand a number of best practices identified by the UN[3], some of which are also presented here.

## 5.1. SINGAPORE WATER MANAGEMENT

Singapore has built a robust, diverse and sustainable water supply from four water sources known as the Four National Taps, that include:

- Local Catchment Water;
- Imported Water;
- NEWater (high grade recovered water); and
- Desalinated water.

NEWater, a cornerstone of Singapore's water sustainability strategy, is high-level reclaimed water. Produced from treated wastewater that is further purified using advanced membrane technologies and ultraviolet disinfection, it is ultra-clean and safe to drink. NEWater has passed more than 150,000 scientific tests and is within the requirements of the World Health Organization.

The second Choa Chu Kang Waterworks (CCKWW) update pushed ceramic membranes on a larger scale in 2016. A new facility was built over three years, costing US$117.4 million. This included the installation of ceramic membranes and the inclusion of ozone-BAC treatment for the plant. In a press release, said that ceramic membranes “are highly durable and should last for 20 years; while polymeric membranes need to be replaced every five years” (Aquatech, 2019).

The Singapore water agency estimates that water loss is significantly reduced from 5% to 1% using ceramic membranes.

[3] https://sustainabledevelopment.un.org/partnerships/goodpractices

## 5.2. ISRAEL - OVER 90% WATER RECYCLING

In 1985 Israel began to reuse treated wastewater for agricultural irrigation and built and managed new regional water networks that provide recycled water. In 2005, Israel introduced desalinated water into the national network. In 2007, to control and regulate all water and sewage problems, the government created the Israel Water and Sewage Authority as an autonomous government agency combining planning and regulatory responsibilities for all the elements of the water chain.

The agency was created to become a one-stop shop for managing all water issues, including utilities, water conservation, water reuse, water quotas, desalination, water technologies, hydrology and pricing.

Israel innovations in the water sector include:

- Drip irrigation;
- Advanced filtration, advanced water;
- Leak detection, rainwater collection;
- New water treatment systems;
- Smart city technologies.

## 5.3. DENMARK - LESS THAN 10% WATER LOSS

Denmark presents extremely low water losses in urban supply systems by using the following technologies:

- SRO systems (a digital system designed to manage, regulate and monitor a facility), containing a module that collects detailed online flow data. The module can be used to detect and locate leaks, plan repairs and trigger an alarm in the event of significant changes in water consumption.
- Model-based leak detection, which is an advanced method by which continuous pressure and flow readings are validated by a mathematical model. The mathematical model can be based on statistics and will alert users if there is any deviation from the norm.
- Technologies such as marker gas and acoustic equipment. The acoustic equipment consists of mobile or fixed units installed in the pipeline grid. There are many varieties of acoustic equipment, depending on the material of the leak.

## 5.4. AIR SELANGOR, MALAYSIA

Air Selangor is the largest water operator in Malaysia, distributing clean and safe treated water to consumers in Selangor, Kuala Lumpur and Putrajaya.

It was set up in 2007 to be the single provider of water services in Selangor and the Federal Territories of Kuala Lumpur and Putrajaya, following a restructuring of the water sector. It currently supplies around 8.6 million people.

2019 marked the culmination of more than a decade of planning to bring Air Selangor to full control of the region's water supply. The acquisition of the state's last remaining concessionaire in April reversed decades of fragmentation and placed the organisation in position to wield economies of scale and bring its service to every single resident in the area.

The group pioneered a new approach to “free water” in 2019. By refocusing subsidies on lower-income households, it secured a more stable financial base without compromising water supplies where they are needed most. With high-end new water infrastructure such as the 200,000m3/d Labohan Dagang water treatment plant coming online throughout the year, water provision in Selangor has been completely transformed for residents.

The organisation made a breakthrough in 2019 tackling the perennial problem of non-revenue water. Through the mass adoption of pipeline sensors and the replacement of more than 300,000 damaged and old meters, the group significantly exceeded its targeted figure and brough NRW down to a record low of 28.73%, saving an estimated 65 million litres a day of water (Awards 2020a).

## 5.5. GUJARAT WATER INFRASTRUCTURE, LTD, INDIA

Gujarat water infrastructure (GWIL) is a state-owned body created to ensure bulk water supply through the establishment of new infrastructure in the arid state of Gujarat, India.

The awarding by GWIL of four major desalination contracts with a combined capacity of 270,000m3/d around Gujarat to an Aquatech/Shapoorji Pallonji team showed that municipal desalination can make a difference in India, and gives the country a new string to its bow when it comes to dealing with the ongoing drought conditions savaging part of the country.

With the four desalination projects to be rolled out under the private finance-supported Hybrid Annuity Model, the deals showed that major infrastructure need not mean a major capital burden on the public purse in India.

It also brought new investors into the Indian infrastructure market and positions the country’s sector well for further PPP development at a crucial time for the country’s water infrastructure.

The Gujarat projects were issued to the market and finalised over the course of 2019 – one of the quickest ever procurement processes for projects of these type and scale, and a stunning breakthrough for contracting in a traditionally torpid project market. It is a hugely positive sign for the numerous future projects set to be rolled out to address water shortages (Awards 2020a).

## 5.6. MEKOROT, ISRAEL

Israel's national water company, founded in 1937 is responsible for bulk supply and management of resources across the country, as well as water supply to neighbouring areas under international agreements.

Israel's already-enviable position as the leading light in combining water with the best of high technology was strengthened further in 2019 by Mekorot as it introduced the best of the world's water technology across the network. From optical fibres to monitor process systems to the rollout of internet-of-things enabled metering systems to the creation of a unique data-drive management system, the company was ready to deploy the best solutions available at every turn.

Solidifying its reputation as a developer as well as a customer of technological excellence, the company launched its WaTech hub in late 2019 to incubate new technologies and widen Mekorot support and investment in the best the "start-up nation" has to offer.

Meanwhile it advanced groundbreaking internally developed tech systems like Meklock – enabling access control to remote sites and saving up to €1 million a year in manual field work costs.

Access to finance is always a tricky issue in water, and Mekorot showed a willingness to explore new areas to support its ambitious goals. Its first-ever public bond issue was three times oversubscribed and ended up raising $280 million, a huge vote of confidence in the body's work and skills (Awards 2020a).

## 5.7. ÁGUAS DE PORTUGAL AND THE "PORTUGUESE WATER MIRACLE"

Águas de Portugal (AdP) is a good example of an attempt to reach universal coverage and sustainability in water supply and wastewater systems at national level that could be useful elsewhere, if conveniently adapted.

In the final decade of the 20th Portugal continued to lag behind European standards in the environmental area. In the early 1990s, water supply networks in Portugal covered a substantial percentage of households, but tap water shortages were frequent with the water commonly unfit for drinking, especially in the summer and drought years. Moreover, only 50% of the water for human consumption was tested and of good quality. In terms of wastewater treatment systems, these served slightly over a quarter of the Portuguese population. These were the circumstances in which AdP was founded in 1993 as a corporate state entity endowed with the objective of reforming the management of the country's water supply and sanitation services.

The company then started out down a pathway of change that in a little over two decades has brought about the reversal of Portugal's environmental prospects concerning water supply and wastewater services. This journey incorporated the experience of EPAL, the century old company integrated into the AdP Group, as its management model and supra-municipal operations were structural contributions to the reform that the sector underwent in 1993.

This change pathway ensured the adoption of integrated solutions that took into account the physical realities of the hydrographic basins and nurturing economies of scale alongside service reliability. This led to the development of a multi-municipal model, applied first to the water supply area in five of the major national regions and gradually extended to wastewater sanitation. The successful implementation of these systems led, as from 2000, to the extension of the multi-municipal model to the whole country, with a special focus on less densely populated areas and inland regions. Thus, the AdP Group set in motion an unprecedented infrastructure plan for the sector, supplemented by the incorporation of the existing municipal infrastructures, some of which underwent renovation or conversion in order to meet the standards and requirements of the new, integrated systems.

Through their respective activities, AdP Group companies have contributed effectively to improving the general quality of life, which clearly reflects in the results returned both in terms of the quality of drinking water (> 99% average safe water in the portuguese municipalities), in the coverage and standards of the water supply and wastewater treatment, as well as in the improvement of bathing water quality standards. The skills and capabilities developed within the context of setting up the multi-municipal systems and in the application of EU investment funds also turned AdP into a sustainable and profitable public company with etic and social responsability behaviour, a central partner for sustainable development, and also an innovation leader on business models, IT solutions, self sufficiency green energy, circular economy water products and a recognized partner for the implementation of projects in international markets.

## 5.8. NATIONAL WATER COMPANY, SAUDI ARABIA

The state-owned national water and wastewater services utility (NWC) is responsible for the supply of potable water and collection and treatment of wastewater for more than 33 million people across the Kingdom.

The colossal bureaucratic challenge of folding rural and outlying areas with disparate needs into the NWC's cutting-edge urban service quality levels was met in 2019 by the company's ground-breaking Hayat digital customer care and billing programme. Successfully completed in an ambitious nine-month timeline, the system merged six legacy systems and 55 million-plus records to a unified system that enhanced customer experiences while transforming the utility's reaction times.

In 2019 the NWC put the final touches to an aggressive smart metering programme that has driven the utility's transformation strategy. Over 2019 a new smart meter was installed every minute on average, cutting the utility's meter reading costs by 75% and creating a wealth of data that allowed it to smash improvement targets – non-revenue water levels were reduced by 3.4% over the course of 2019 alone.

Last year saw the start of procurement for the NWC's regional "management, operation and maintenance" contracts, under which the private sector will be invited to support and improve utility services in a way and scope never before seen in the region. Rigorous planning and thinking outside the box meant the NWC and its advisors are now finally positioned to allow private sector expertise to pay off for tens of millions of people in the Kingdom (Awards 2020a).

## 5.9. KAMSTRUP

Kamstrup's is a Danish metering specialist in the field of water and electricity. Kamstrup's new smart water meter has dramatically raised the bar for intelligent water metering solutions, its in-built acoustic leak detection capabilities helping reduce leaks in service connections, a traditional blind spot for utilities. In one test, 17 leaks were found in an area where 50 meters were installed, reducing water loss from 1.7m3/hr to 0.3m/hr once repaired. Warm market reception has already resulted in two large projects wins in Denmark as well as dozens of major sales across Europe (Awards 2020f).

## 5.10. NIJHUIS WATER TECHNOLOGY B.V.

Nijhuis Water Technology is an industrial wastewater specialist with more than a century of history that has evolved into one of the premier water technology companies around today.

New technologies in the fields of ammonia recovery, fat recovery, intelligent chemical dosing and sludge dewatering have enabled Nijhuis to rapidly expand business previously focused on wastewater treatment for slaughterhouses. The benefits of these technologies can be quickly felt by clients, with Nijhuis' ingenious modular solutions strategy enabling rapid plant start-up times in tiny footprints for demanding industrial customers, as well as boosting its growing mobile water treatment expertise (Awards 2020f).

## 5.11. NYEWASCO, KENYA

The Nyeri Water and Sanitation Company, otherwise known as Nyewasco, is the water and wastewater service provider for the city of Nyeri in Kenya. It was established in 1997 and now serves around 800,000 people.

Nyewasco's operational performance has been head and shoulders above other water utilities in the country, bringing non-revenue water levels down to just 16% in 2019, compared to the national average of 41%.

Nyewasco extended its successful urban coverage into low-income areas and informal settlements in 2019 by radically rethinking its customer service charter and making a 'pro-poor policy' central to its decision-making strategy.

The utility's steep upward trajectory with regards to performance is reflected by its booming bankability. Nyewasco was one of only three utilities – out of Kenya's 72 – to be given a clean bill of health in the 2019 national audit, showing it has effective utilisation of public funds and best management practices at its very heart (Awards 2020e).

## 5.12. OBRAS SANITARIAS MAR DEL PLATA-BATÁN, ARGENTINA

Obras Sanitarias Mar del Plata-Batán (OSSE) is the municipal water utility operating in Mar del Plata, Argentina, providing water, wastewater and rainwater capture services to more than 600,000 people.

OSSE completed major network extensions in 2019, including upgrades that now provide 10 hours of water reserve, a crucial development in an area where shortages can be a risk. The works completed mean the area now has 97% coverage for both water and wastewater services, significantly improving the living conditions of the local population. Meanwhile, the improvements to infrastructure have significantly reduced maintenance costs and driven energy efficiency for the utility.

The utility made major breakthroughs on key water projects in 2019. It completed its Acueducto Oeste System programme, a project which included 74 wells which increase water production, as well as the extension of the Mario Bravo Supply Center, adding further to the region's reserve capacity.

On top of this, the utility made major operational improvements at the Talcahuano Water Lift Station which is the primary link to the Southern Aqueduct groundwater system. The upgrades extended the life of the station by at least 30 years and means it now operates automatically, with equipment that mean supply varies only according to the demands of the water distribution network, eliminating wastage (Awards 2020e).

## 5.13. OFFICE NATIONAL DE L'ASSAINISSEMENT DU SENEGAL

The national sanitation utility of Senegal (ONAS) serves more than 15 million people over an area of almost 200,000 km2.

ONAS made tailored plans for both rural and urban communities a priority in 2019 in an effort to ensure sanitation for all is achieved in the fastest and most efficient way. Across the country, the number of sanitation connections increased by 375% in the past year, and this figure is projected to increase this by another 117% in 2020.

Driving the successful increase in sanitation in Senegal was the construction of a new fecal sludge treatment plant and the introduction of an 'omni processor unit'. The 400m3/d unit has not only increased sanitary living conditions, but contributed to the circular economy through the generation of electricity and production of recyclable ash.

Three new models of innovative toilets tailored for flood zones area being used. These new models have reduced the average cost of pit emptying in the country from $51 to $38. By combining community involvement and market-leading technology with local application, the utility is rapidly becoming a model for disruptive innovation in the water and sanitation sector, improving and integrating the non-sewered sanitation value chain (Awards 2020e).

## 5.14. OFFICE NATIONAL DE L'EAU ET DE L'ASSAINISSEMENT DU BURKINA FASO

ONEA, the Office National De l'Eau et de l'Assainissement Du Burkina Faso, is the national water utility of Burkina Faso, providing water and sanitation services to the country's population of more than 18 million.

ONEA kickstarted the implemented of its 2019-20 Water Supply and Sanitation Program (PAEA) to improve access to drinking water and sanitation in urban and rural areas. The programme includes constructions of 300 boreholes, including a dozen high-speed boreholes already under way to supply drinking water in previously underserved areas.

The utility completed the construction of its second major treatment plant and laid new pipes to connect Ziga and Ouagadougou, building greater resilience into national-level water security.

While the demand gap that led to the construction of the plant was estimated at 59,922,500 m3/year, the utility has built in extra capacity (up to 95,690,000 m3/year) to hedge the risk of continued or even more extreme water scarcity.

Distribution systems were strengthened between the two major branches of the utility in the country's northern and southern regions. Significant amounts of pumping reinforcement equipment were installed in order to integrate previously isolated systems, a move that has generated greater resilience against localised water scarcity and enhanced clean, safe water access for thousands of residents (Awards 2020e).

## 5.15. ISTANBUL WATER AND SEWERAGE ADMINISTRATION (ISKI), TURKEY

ISKI is the water and wastewater utility for Turkey's largest city, Istanbul, serving more than 15 million people across an area of 5,461km$^2$, through 22,000km of water transmission lines, and 22,000km of wastewater lines. In Istanbul it operates 21 potable water treatment plants and 87 wastewater treatment plants.

ISKI has been the first in Turkey to deploy 'E-Exploration', a unique eco-friendly software which rapidly coordinates water service commencement requests. It has increased the rate at which residents are able to apply for access to clean safe water, with the electronic method taking only 24 hours from start to finish compared to 4 days under the manual method.

A centralised system for monitoring Water Quality in ISKI's distribution network has been implemented which operates with a long-distance signal, taking multiple measurements and multi-locational samples, instantaneously. It measures residual chlorine, PH, and temperature which support disinfection, control of flavour and scent, and prevention of biological build-up.

Digitisation of the system allows the utility to perform more accurate water quality testing and evaluation while saving time, reducing labour needs, and using fewer vehicles.

The utility has internally developed a new reservoir management technology to address the city's increasing challenges of water scarcity, population growth, and water quality. The technology, which was first deployed in imrahor, covers the reservoir with a locally-produced biodegradable film which reduces evaporation by 30%, lowers the cost of purification, prevents eutrophication, and creates a community recreation space (Awards 2019b).

## 5.16. CHOA CHU KANG WATERWORKS UPGRADE, SINGAPORE

A mass-scale ceramic membrane upgrade is used in Singapore's largest water treatment plant. Half of the plant's 362,000m3/d treatment capacity, where polymeric membranes were originally installed in 2008, was upgraded to ceramic ultrafiltration (UF) technology, followed by an ozone-biological activated carbon filtration (BAC) process.

Choa Chu Kang is now the largest ceramic membrane drinking water facility in the world, marking a new level of success for the technology. The cutting-edge material deployed increases the membranes' lifespan to an unrivalled 20 years, making it a superlative economical solution based on the kind of life-cycle cost analysis that is increasingly driving utilities' balance sheets.

The adoption of ceramic membranes allowed designers to implement continuous, in-line pre-ozonation which cleans the membrane surface as it filters the water. This, in turn, increases the membranes' recovery rate to over 99% and reduces opex by saving on disinfectant downstream.

The ozone-BAC process following membrane filtration improves the plant's robustness in the face of changing raw water quality. As climate change increases the frequency of algal blooms in Singapore's reservoirs, this strengthened treatment process is crucial to the island-nation's supply resilience at a time when its water resources are coming under increasing strain (Awards 2020d).

## 5.17. MONTEVINA WTP UPGRADE, USA

A complete modernisation of the treatment train took place at San Jose's 113,500m3/d Montevina water treatment plant. The 50-year-old facility has been retrofitted with seven ultrafiltration (UF) trains and two reverse osmosis (RO) trains for backwash water recycling and increased recovery.

The UF upgrade now enables the plant to treat raw water with far higher turbidity than before, leading to fewer shutdowns at a crucial piece of infrastructure for the city. Prior to the improvements, Northern California's winter storms would lead to frequent plant shutdowns as the feedwater exceeded the 15 NTU limit of the previous treatment train. The UF facility can now handle 100 NTU in normal conditions and up to 500 NTU during storms, virtually proofing it from the elements. This has enabled San Jose Water to provide better service and take fuller advantage of abundant winter water.

The plant's new RO system, installed in addition to the main UF train, allows a greater recovery rate as it processes backwash wastewater to reintroduce it into the supply. This enables San Jose Water to make more efficient use of their surface water resources in a context where climate change is rewriting standard operating rules and making seasonal droughts more common.

The project's sustainable approach was not limited to the treatment train: construction was planned so as to repurpose existing concrete structures rather than spend time, money and energy tearing them down and rebuilding from the ground up. The construction team also used screw presses to reduce solid waste volumes, which made disposal more efficient and required less traffic in the nearby residential neighbourhood (Awards 2020d).

## 5.18. PUTATAN 2 DRINKING WATER PLANT, PHILIPPINES

Putatan 2 is a new 150,000m3/d water treatment plant serving Metro Manila. It was built next to the Putatan 1 plant, commissioned in 2011, to serve an additional million people in concessionaire Maynilad's service area.

In a year when the Filipino capital faced major water shortages and consistently low levels in the Angat dam which provides most of the city's water, the opening of the Putatan 2 plant saved the day by allowing west zone concessionaire Maynilad to improve the resilience of its supply, a crucial move for the concessionaire at a time when private water has come under fire in the country. The plant's intake draws from a different freshwater source, Laguna Lake, vastly increasing the security of the city's water resources.

Putatan 2 deploys world-class membrane technology on a simply unprecedented scale in the Philippines. Following DAF and BAF pre-treatment, the water goes through ultrafiltration followed by reverse osmosis, before a final chlorination step.

Laguna Lake's waters are considered to be among the world's most challenging to treat due to a high concentration of algae and suspended solids. Putatan 2's state of the art technology is helping Manila breaking through to this previously-untappable resource with complete ease (Awards 2020d).

## 5.19. TAI PO WATER TREATMENT WORKS EXPANSION, HONG KONG

A project to double the capacity of the Tai Po Water Treatment Works to 800,000m3/d, making it the second-largest WTP in Hong Kong. The plant now features on-site chlorine and ozone generation facilities and achieves zero liquid discharge of process wastewater.

The expansion made Tai Po the world's largest municipal water treatment plant to generate chlorine on-site. This innovation is a boon for the area's public safety as it eliminates the risks associated with transporting and storing chlorine at the plant. Chlorine consumption is also reduced by 30% thanks to ozonation.

With the site surrounded by steep hillsides, the project adopted an innovative stacked design to adapt to the space constraints of its immediate environment. This compact solution saved approximately 32% of land area compared to an equivalent "flat" WTP and enabled the WSD to increase capacity even where land is at a premium, a hugely important achievement for a space-restricted location like Hong Kong.

The plant has put in place a zero liquid discharge system for process wastewater which returns backwash water and sludge dewatering filtrate to the plant's inlet and uses sampling water as well as harvested rainwater for irrigation on the plot. Sludge from the treatment process is also used as soil conditioner for the plant's green areas and may in future be turned into pavement blocks. The plant is a model for the circular economy (Awards 2020d).

## 5.20. ALMAHSAMA DRAINAGE RECYCLING, EGYPT

A 1,000,000m3/d wastewater treatment and reuse project in Egypt's Sinai Peninsula. Wastewater from Mahsama will be transferred to the new WWTP through two tunnels, after which it will provide irrigation water to approximately 50,000 hectares of land in the peninsula.

Almahsama is the largest reuse project of its type in the world and represents a pioneering step for water reuse and recycling in Africa, where it is still evolving as a sustainable solution to water scarcity.

The plant will provide a new source of water wealth for the peninsula, creating a new generation of job opportunities in the agricultural sector and contributing to the development of new communities in the area. It also represents a significant step in improving the environmental condition of the peninsula.

Previously untreated wastewater would flow into the Temsah lake, causing severe consequences for animal habitats and local fishing culture (Awards 2020b).

## 5.21. HUBEI ITEST DECENTRALISED TREATMENT, CHINA

A decentralised wastewater treatment project in Hubei province, China, involving the installation of around 80 packaged membrane aerated biofilm reactor (MABR) units at service areas and tolls every 50km along the province's highway networks. To date, the project has delivered units offering a combined wastewater treatment capacity of more than 9,000m3/d.

The MABR L4 and S1 systems offer highly efficient nutrient removal, ideally suited to the high-nitrogen content of the Hubei influent. The units employ simultaneous nitrification and denitrification which result in opex savings and perform reliably in all four seasons and peak travel season variations.

The modular design serves as an industry pilot for domestic wastewater treatment in the highways field. The units are assembled, tested and packaged in Fluence's manufacturing plants, meaning fast and efficient installation upon delivery.

The fastest commissioning of a unit in the project so far has been under four weeks. Additionally, the plants can be remotely monitored and operated in real time via smart device, significantly simplifying the O&M needs of the operator (Awards 2020b).

## 5.22. KOYAMBEDU TERTIARY TREATMENT RO PLANT, INDIA

A 45,000m3/d reverse osmosis plant and transmission pipeline was built in Koyambedu, Tamil Nadu, treating wastewater for reuse at an industrial hub.

The plant is the largest and most technologically advanced reuse project in India. It is the first reuse facility in India to use ozonation for disinfection and marks a decisive step for the country's ambitions for municipal water recycling. Furthermore, with the completion of the TTRO, Chennai is now the first Indian city to reuse more than 20% of its treated wastewater.

The project will boost Chennai's water resilience and sustainability in the wake of the city's ongoing struggles with drought and water scarcity.

The TTRO will help free up over 16 million m3 of freshwater each year, securing water supply for Chennai's population of more than 10 million people.

The TTRO uses a multi-stage treatment scheme, including ultrafiltration, reverse osmosis, rapid gravity sand filters, and ozonation. The UF and RO membranes achieve a recovery rate of 75%, and the plant has an ultra-low specific power requirement of 1.88kWh/m3, which is expected to incur significant savings in the plant's operating costs over the next 15 years (Awards 2020b).

## 5.23. PASO ROBLES WWTP, USA

A tertiary treatment upgrade was made at the 18,546m$^3$/d Paso Robles WWTP, California, including the development of a nutrient harvesting system, with treated water used for irrigation at local farms, golf courses and parks.

The project massively improved the plant's physical and environmental footprint and serves as the first step in the city's long-term plan to create a resilient and sustainable water supply. The expanded WWTP converts wastewater into California Article 22-compliant recycled water for irrigation, a crucial move in supporting the city's water resilience.

The nutrient harvesting system was conceived and developed during construction of the tertiary treatment facilities when it became evident that lower flow conditions had caused a struvite build-up in piping and equipment.

In addition to preventing struvite build-up, the harvesting system keeps phosphorus, nitrogen and ammonia from overloading local and state water resources. It also produces a commercial-grade fertiliser which can be sold to subsidise operating costs.

The flexibility of the design means the plant can send water to the Salinas River when demand for recycled water is low. The tertiary treatment process flows by gravity, eliminating the need for pumping and thereby saving equipment and energy expenses. Additionally, repurposed secondary sedimentation tanks that had previously sat unused allow disinfection processes to operate continuously and at a more constant rate (Awards 2020b).

## 5.24. MEXICAN/GERMAN PARTNERSHIP TO ENABLE A MASSIVE IMPLEMENTATION OF INNOVATIVE, OFF-GRID, DRY SANITATION TECHNOLOGY AT RURAL AREAS IN MEXICO

Within the collaboration between Rotoplas (leading manufacturer of water and sanitation products in Latin America) and 3P Technik (German technology provider in the field of autonomous sanitation), a 6-month field test is realized at 8 representative locations in Mexico. Aim of the study is the evaluation of market acceptance from users and relevant public authorities for the innovative dry toilet technology, which provides a sustainable solution for rural sanitation. The midterm objective is the local manufacturing of the sanitation system ensuring the scaled availability of the solution at market prices to enable the realization of corresponding governmental sanitation programs within SDG's frame.

## 5.25. MEXICAN PROGRAM FOR RAINWATER HARVESTING IN RURAL AREAS (PROCAPTAR)

Drinking water and sanitation coverage at the Mexico are 92.5% and 91.4%, respectively. However, the coverages are smaller in rural areas, with an estimated population of 4.5 million Mexicans lacking water service.

Reducing the coverage gap in rural areas represents a major challenge, due to the high dispersion of houses, which makes it unfeasible to provide services to the most remote communities. Moreover, due to the conditions of the inhabitants of such areas, the conventional drinking water and sanitation service through pumps and pipes is often unsustainable because of the impossibility of the users for covering the systems' operation costs.

PROCAPTAR represents an option for supplying water to people that lives in rural areas and need to travel long distances for having access to water, as well as to improve their living and health conditions by giving them access to a sanitation system. More specifically, the objective of PROCAPTAR is to promote social development, water and sanitation access of most marginalized houses in rural areas through rainwater harvesting and storage, and wastewater treatment technologies at the household level.

The program considers a system for wastewater collection, treatment and disposal. It consists in a treatment system at the household level, with a biodigestor or a treatment reactor specially designed which will permit to dispose of wastewater properly, avoiding pollution of the environment that surrounds the house.

## 5.26. GUIDE TO SUSTAINABLE URBAN DRAINAGE TECHNIQUES

A Guide was developed in Brazil (municipality of Campo Grande) to disseminate sustainable techniques for urban drainage techniques, including micro-reservoirs, permeable floors, infiltration wells, rain gardens, grasslands, infiltration trenches, and infiltration trenches + green roofs.

The main purpose of this Guide is to demonstrate, through simple conceptualization, schematic drawings and calculation memory, the effective and clear applicability and comparison of these devices in the urban environment of the city of Campo Grande, primarily at the public and private lot scale. The publicizing of techniques to professionals and entrepreneurs, encouraging their use in drainage projects, will contribute to the reduction of the flow directed to macrodrainages, thus helping urban growth in an orderly and less environmentally impacting way.

## 5.27. ÁGUAS DO PORTO AND ÁGUAS DE GAIA

Águas do Porto and Águas de Gaia are some of the earlier examples of integrated management of the urban water cycle, including rehabilitation of urban streams and urban beaches, with overall great environmental, economic and social impact

The public water supply and wastewater systems of Porto have been developed over the past 120 years. From 2006 onwards, with the constitution of Águas do Porto (AP), the urban water cycle, as a whole, was integrated under a single unified management structure, including the rehabilitation of urban streams and beaches.

Starting from a complex situation, with excessive complaints from customers about service quality, high levels of water loss at 54% of the system input volume and polluted beaches, the following goals were set:

- To supply potable water, continuously, everywhere in the city;
- To drastically reduce water loss;
- To connect all buildings to the public sewerage system;
- To clean and rehabilitate the urban streams;
- To rehabilitate beaches to Blue Flag status; and
- To manage and expand the stormwater system.

With a new organizational chart of the water utility, made very simple and flat, these objectives were quickly met, including the reduction to half of the non-revenue water (NRW) in just eight months. Moreover, pollution of the main urban streams decreased by a factor of ten within a year.

This was achieved through the elimination of sewage discharges to the stormwater system, mostly due to illegal connections from houses and industries. Also, in less than a year the water quality of the city's beaches met the European bathing water standards. This surprisingly fast reduction of the microbiological pollution resulted from the elimination of discharges of polluted stormwater in the beaches in dry weather, as this polluted stormwater was by-passed to the wastewater system for joint treatment.

By 1998, the neighbouring municipality of Vila Nova de Gaia had also high levels of NRW of around 47% and the wastewater service was rudimentary, with only 10% of properties connected to the public sewerage system. There were no wastewater treatment plants at that time and raw sewage was discharged directly to water bodies. Consequently, the popular sandy beaches along the 17 km coastline were grossly polluted.

With clear political support, professional management, motivated workers and the possibility to apply for financial support from European Union structural funds, it was possible to pursue the following priority objectives:

- To complete the water supply system in order to guarantee potable water of high quality, 24 hours per day, everywhere in the municipality;
- To complete and extend the wastewater system and to connect all properties in the municipality to the public sewerage system;
- To clean and rehabilitate the urban streams; and
- To rehabilitate and obtain Blue Flag status for all beaches in the municipality.

As a result of the efforts made since then, NRW was reduced from 47% to 20% over six years. The corresponding savings helped to finance a new wastewater system built almost from scratch.

The principal urban streams were successfully cleaned and rehabilitated whilst the 17 km of beaches have been improved to Blue Flag status, the highest quality level in Europe. Over 30 km of footpaths were also built along the urban streams and coastline, allowing people to benefit from unpolluted waterfronts.

## 5.28. WINDHOEK, NAMIBIA

Namibia is one of the most arid countries in Africa: the average rainfall is 250 mm per year and the heat causes 83% to evaporate, with only 1% of rainwater infiltrating into the ground. Consequently, the water supply of Windhoek - located in central Namibia - depends mainly on boreholes and three dams located 60 and 200 km away. To cope with shortages, the city has sought alternative solutions to secure its water supply.

In the Namibian capital, which is home to 350,000 people, every drop counts. So in 1968 the municipality built the Goreangab wastewater recycling plant.

Due to the fact that all naturally available water sources in the around Windhoek have been fully harnessed, the New Goreangab Reclamation Plant was completed in 2002 and comprises the latest available proven water treatment technology. This was done in order to ensure the total utilization of available effluent from domestic wastewater to ensure the security of water supply for the future.

The facility features state-of-the-art "multi-barrier" technology: ozone treatment, ultra membrane filtration and residual chlorination. This process eliminates all pollutants and contaminants. The various treatments, coupled with rigorous bio-monitoring programs, guarantee high quality, safe drinking water.

## 5.29. WATER FOR ALL PROGRAM

Water for All program was created to achieve universal and adequate access and use of water to populations that do not have access to this public service in the State of Maranhão, Brazil. Data from 2017 (SNIS) indicates that only 52.70% of the population of Maranhão has access to water supply,

To this end, investments in the expansion and improvement of Water Supply Systems, drilling of wells and acquisition and installation of micro and macromeditors are being carried out throughout the Maranhão state.

More specifically, the actions include:

- Increasing the water production in most systems through drilling and maintenance of wells, improvement and increase of water storage capacity with the construction and maintenance of water tanks, replacement and expansion of water distribution networks, and new connecting branches (works in the amount of approximately R$ 48 million were contracted);
- Water Supply Revitalization Program. In general, the main improvements of this action involved the expansion of the distribution network, recovery of Water Treatment Station, reform and improvement of Gross and Treated Water Pumping Stations, recovery of water tanks and maintenance of wells and new connecting branches, contemplating new residents with running water. Contracted value of approximately R$ 13 million;
- Rehabilitation and operational improvement of the Italuís system: The delivery of this important work allows the

Italuís System to improve water supply of the population of São Luís, with a planned increase of 500 liters per second, approximately 30%, benefiting 600 thousand people, in 159 neighbourhoods of the capital. Contracted value of approximately R$ 129 million;

- Rehabilitation and operational improvement of Imperatriz and Açailândia's systems: With the expansion of Imperatriz's distribution network, 50km of network were replaced and expanded and 2,000 new branch lines were deployed, with a contracted value of approximately R$ 12 million;
- Growth Acceleration Program - PAC (Water System): The main advance of this action was the implementation of water production and distribution in the municipality of Tutóia. Contracted amount of approximately R$ 41 million;
- Wells drilling: The main result of this action is the increase of water production in the municipalities. Contracted value of approximately R$ 51 million;
- Simplified Water Supply System (SSAA): This action increases the production of water in the regions where it is carried out, with actions such as wells drilling and water tanks construction. Contracted value of approximately R$ 9 million;
- Acquisition and installation of macromeditors in São Luís: All macromeditors are in full operation and allow a better management of the Company. Data on the flow and volume of water produced and distributed to the city's districts are made available on the internet. Contracted value of approximately R$ 1 million;
- Acquisition and installation of water meters in São Luís: Up to now more than 21 thousand water meters have been installed, increasing the São Luís hydrometric index from 23% to 32%. Contracted value of approximately R$ 27 million.

As the Program involves the hiring of companies specialized in the provision of engineering services and supply of materials for the entire state of Maranhão, a challenge emerges in this market which is still under development, with difficulties in establishing partnerships. In this way, the promotion of good practices is of great importance.

Institutional challenges are also present in the implementation of the Program, due to the need of coordination with local authorities. The conciliation of civil works with local dynamics, employment relations, the use of sustainable techniques and innovations in general may find some resistance from local actors. Management and economic-financial sustainability of Water Supply Systems can also represent a difficulty, depending on local factors.

## 5.30. MAJIK WATER

In short, Majik Water harvests drinking water from air using desiccant materials to adsorb water and solar thermal heat to release this for collection.

Determined to end Kenya's water crisis, Beth Koigi, CEO of Majik Water, has designed a machine that harvests clean, potable water directly from moisture in the air. There is six times more water in the air compared to all the rivers of the world combined and, by tapping into this seemingly limitless resource, Majik Water offers a sustainable water solution for millions of Kenyans.

Majik Water units come in various capacities, with the smallest one providing 25 liters per day of water, and the largest one supplying 1000 litres per day (larger capacity tanks are attached externally). These figures are based on relative humidity levels of 60 percent and a temperature of 25 degrees Celsius. Nevertheless, Water units can still supply water at relative humidity levels as low as 35 percent.

Majik Water units contain three levels of water treatment systems, including reverse osmosis, an activated carbon filter. Majik Water units can be customized to work on solar energy or a generator.

At the moment, a 500-liter Majik Water unit costs $12,500. The first model operates as pay-as-you-go: people can buy a liter of water from the device for as low as $0.01. This model utilizes the smaller capacity units which function like paid water dispensers. The second model offers water solutions to corporations and NGOs whereby the machine can be used to meet various company demands, be it water consumption or industrial usage.

## 5.31. THE OSTARA NUTRIENT RECOVERY TECHNOLOGIES PROJECT IN CHICAGO

The Stickney Water Reclamation Plant is the biggest single source of phosphorus in the entire region that drains into the Mississippi River.

A $31 million project of the Vancouver-based Ostara company diverts wastewater through three reactors that use catalysts to form tiny, nutrient-rich "pearls" for the fertilizer industry. It is estimated that the equipment will produce up to 10,000 tons pearls a year, reduce the Stickney plant's phosphorus discharges by about 30 percent.

The Ostara has upgraded other smaller plants in the U.S., Canada and Europe.

## 5.32. GROUNDWATER MANAGEMENT IN ORANGE COUNTY (CALIFORNIA)

Orange County Water District (OCWD) is responsible for managing the vast groundwater basin that provides most of northern and central Orange County's drinking water. As part of its groundwater management, OCWD maintains one of the world's most advanced aquifer recharge systems to replace the water that is pumped from wells belonging to local water agencies, cities and other groundwater users.

OCWD works to manage and protect groundwater in three main ways:

**1) Recharge**

OCWD captures surface water from several sources. Water is collected and contained, then added to the groundwater basin to recharge it. Recharging is a natural hydrological process. Water moves down from the surface into the groundwater basin to replenish the aquifer. OCWD helps nature move the water along with a system of pumps, pipelines, levees, and filters.

Recharge facilities: Percolation basins slowly put water back into the groundwater basin while naturally filtering and purifying it

Diversion facilities: Inflatable rubber dams, levees and valves direct the water to recharge facilities

Barrier wells: These wells allow water to be pumped into the groundwater basin to keep seawater from contaminating the basin

**2) Monitoring**

OCWD monitors and protects water quality and quantity—always maintaining sustainable water levels in the basin. To keep the groundwater from being contaminated, it manages seawater intrusion. In addition, OCWD checks for harmful chemicals, investigates groundwater contamination and tests the water that is in, and going into, the basin. OCWD also monitors the quality of drinking water wells.

Monitoring wells: These wells allow for measuring water elevations and taking water samples

Production wells: Groundwater is pumped out of these wells

Advanced Water Quality Assurance Laboratory: the Lab tests water quality

**3) Purifing**

OCWD percolates and injects water into the basin. Some of it is recycled water.

Groundwater Replenishment System (GWRS): The GWRS reuses treated wastewater and purifies it to supplement drinking water supplies

Wetlands: Shallow ponds with vegetation are used to purify water naturally

## 5.33. L'OREAL 'DRY FACTORY'

Cosmetics Company L'Oréal is implementing a 'dry factory' concept to reduce water consumption in its manufacturing operations worldwide. The concept of the dry factory means that the municipal water consumption is reduced to just two essential uses – domestic water use of the employees and for the production of water that serves as raw material for the products. For the rest of the processes and utility uses, no additional fresh water is used.

The concept focus on water efficiency, but also includes the reuse of water and the closing of production loops by developing recycling projects.

Each factory has a different type of wastewater and since high quality water is required, membrane technology is normally used.

The wastewater contained surfactants, grease and different types of polymers, so a strong pre-treatment and control mechanisms are needed before membrane treatment.

## 5.34. HYDRALOOP

This system, designed for individual houses, uses decentralized water recycling.

Hydraloop collects, cleans and re-uses the water from showers, baths, washing machines, handbasins and air conditioning units. The resulting water is clean, clear, safe, and disinfected. It can be re-used for toilet flushing, washing machines, garden irrigation and topping up swimming pools.

Hydraloop offers turn-key products and made to measure solutions for projects of any size.

## 5.35. CONFEDERACION HIDROGRAFICA DEL EBRO. FIRST RIVER BASIN ORGANIZATION IN THE WORLD

Ninety five years ago, in March 5, 1926, the first river basin organization in the world was born: the Confederación Hidrográfica del Ebro, in the most important river basin in Spain. If this organization stands out for anything, it is because over the decades it has applied the principle of respecting river basin unity in water management to serve its functions, adapting to institutional and bylaws changes.

Milestones (birth, Water Law, Water Framework Directive), data (475 million annual records from basin networks; management of 55 state dams and 1,500 kilometers of canals, 68,000 parameters analyzed annually in the Water Quality Laboratory), its documentary heritage.


*Official coat of arms of CH Ebro, since its creation March 5, 1926*

*One of the first works: Tardienta Aqueduct, in Riegos del Alto Aragón, the largest irrigable area in Europe*

*Manuel Lorenzo Pardo, Civil Engineer, its great driver and first Director*

**The early years**

The Ebro Trade Union Confederation is conceived as a technical and economic project to take full advantage of the hydraulic resources of the Ebro river basin. Manuel Lorenzo Pardo, its first Technical Director, wondering about the developments that the Confederation had brought, identified them in harmony, the coupling of interests, in the sum of well-oriented efforts, being the same interested agents of their own benefit.

The Confederation was born as an ambitious project. In addition to engineers and technicians of studies, construction, conservation and exploitation of infrastructures, it has services of agronomic, forestry, mine and industrial applications, mathematical statistics, hydrography, meteorology, geology, laboratory, geographical and cartographic work, valuations, expropriations, architecture, social inspection, and even healthcare; this, as an example, dedicated to the study and application of prophylactic means aimed at avoiding the endemics of irrigation in its period of human adaptation, such as malaria and anlostomiasis.

The irrigation of large areas of dry Spain as a way of overcoming the secular backwardness of the country is the general idea in which an initiative such as the creation of the Hydrographic Confederations can be framed. This is perfectly understandable, considering that we were in a purely agricultural country (with more than half of its population occupied then in this activity).

Those initial decades are linked to the construction and development of hydraulic works. Between 1929 and 1980 many dams for regulatory reservoirs of the Ebro were built, and important irrigated areas were put into operation, in addition to the irrigations secured with the regulatory reservoirs and the improvements introduced in the main existing Canals.

**The collegiate bodies**

From the beginning it served as support for a management participated by users, at birth as a Trade Union Confederation and after ninety-five years continues to integrate, through its collegiate bodies, decision-making in an integrated way for the whole basin, in an environment of much more complexity.

The Collegiate Bodies are the greatest exponent of participatory democracy in the management of the basin, which responds to a model that has been present since the birth of the Confederation, in which users have a voice and vote over all their lines of action. Now, administrations, users and social agents have representation in them.

**Evolution to the present**

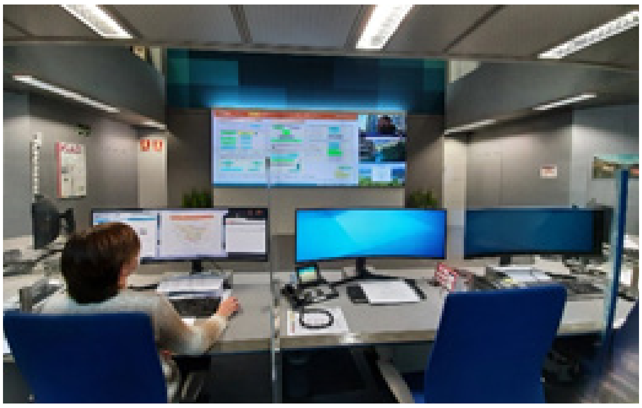
Changes in political and social reality over the past four decades have been accompanied by changes in the regulatory and institutional framework that have expanded the responsibility of river basin agencies and transformed governance conditions.

Therefore, since the 1980s Hydrographic Confederations have not merely provided services, in the field of the construction and operation of hydraulic works, but assume important roles in the management and protection of the hydraulic public domain, hydrological planning and integrate in their collegiate and governing bodies the participation of regional governments. They play projected competencies over the management of watershed agencies and play a key role in hydrological planning.

Multidisciplinary teams, led by engineers, carry out the integrated management of water resources, providing water in quantity and quality to consumptive demands of 8,190 hm3/year, where agricultural (more than 900,000 ha in irrigation) and urban demands stand out. And it is obtained a significant production of hydroelectric, clean and renewable energy, variable between 5,000 and 9,000 GWh/year, depending on the hydraulicity of each year.

The Water Quality Laboratory, the inspection of wastewater harvests and discharges, and the work to achieve a good state of the water bodies, surface and underground, together with an integrated management of the water resource to ensure water safety, currently focus the work of the basin organism.

*The CHE Laboratory is a reference center with international accreditation for the control of more than 500 parameters (substances or groups of substances) in water, sediment and fish masses.*



*The SAIHEbro controls 90 reservoirs, 347 precipitation sensors, 194 ambient temperature sensors, 42 weather stations, 374 stations in irrigation systems, 80 stations for piezometric network control and 138 stations for the control of other uses such as hydroelectric, geothermal and fish farms*

A modern information system, the SAIHEbro, meets two objectives: forecasting, in flooding situations (and managing episodes with an SAD Decision Aid System), but also in drought, to have data for decision-making and global management of water resources to optimize their allocation and exploitation. In its conception, implementation and management, engineering is the main vector.

## 5.36 SPAIN´S SEGURA RIVER: WASTEWATER REUSE AND RIVER RESTORATION

The Segura River Project has successfully restored the health of the river, with advanced wastewater schemes now supplying reclaimed water to the agriculture industry which rapidly boomed after Spain became a member of the European Union. This once polluted and water-stressed river in Europe's driest basin has been transformed from an exposed sewer to a healthy, vibrant river, home to otter, migratory birds, and other flora and fauna, and the reuse of irrigation water has allowed increased agricultural, leisure and recreational activities.

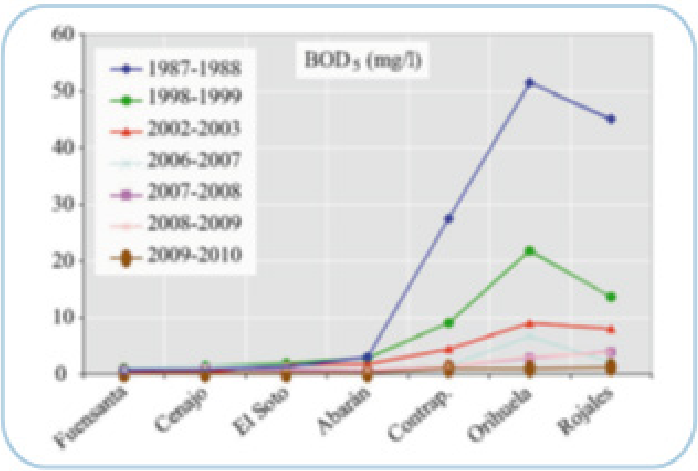
**Project Overview**

The Segura River is about 350km long and flows from west to east discharging in to the Mediterranean on Spain's east coast. The river passes through the entire region of Murcia which has the lowest annual rainfall in the European regions yet a population of over two million. The basin experiences an acute supply-demand imbalance as illustrated by the water scarcity index with demand exceeding the natural stream flow by 2.5 times; consequently water that is available in the river is of extremely poor quality thus further reducing resource availability. The basin is supplemented by an inter-catchment transfer from the Tajo river and desalination. Of a total demand of 1 900 million m3/yr, 87% is for agricultural use and 10% for municipal use.

This project, implemented over a 10-year period, and with the contibution of more tan 100 engineers, improves available resource through the capture and treatment of urban and industrial waste water flows and returning them for direct or indirect re-use in irrigation.

A key element to the project's success was the enaction of policy and legislation that enforces the "Polluter Pays" principle; this enabled waste water treatment and recovery to be operated on a cost recovery basis.

*Agriculture was an economic driver for river restoration.*




*Water quality improvement.*

**Key Elements**

- Transfer of the mandate for wastewater collection and treatment from municipalities to a region wide General Directorate of Water.
- Establishment of Esamur, an independent agency for operation and maintenance of treatment facilities and collection of waste water levies.
- Construction of 97 advanced waste water treatment plants.
- Construction of 350km of sewer.
- Introduction of a robust system for the monitoring of industrial discharges to sewers.
- Implementation of industrial wastewater treatment at source.
- 75-80% co-funding from European Funds.

**Main Project Levers**

- **Construction of a region-wide wastewater collection and treatment system:**

  All 97 advanced wastewater treatment plants were designed to allow nutrient removal and, where necessary, tertiary processing to minimise concentrations of suspended solids and disinfect the reclaimed output. This was done to improve environmental quality and safety for direct and indirect reuse.

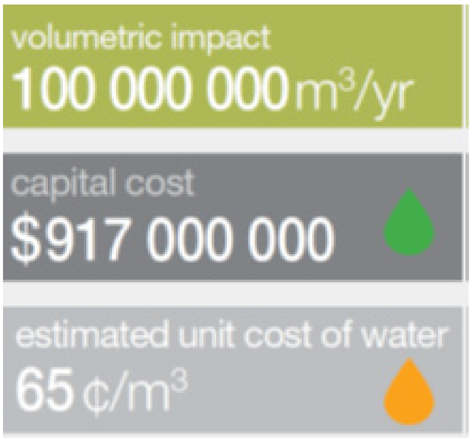
  By 2010, the wastewater collecting system connected 99% of the urban population of Murcia region to the corresponding treatment plants. Approximately 350km of sewers have been built.

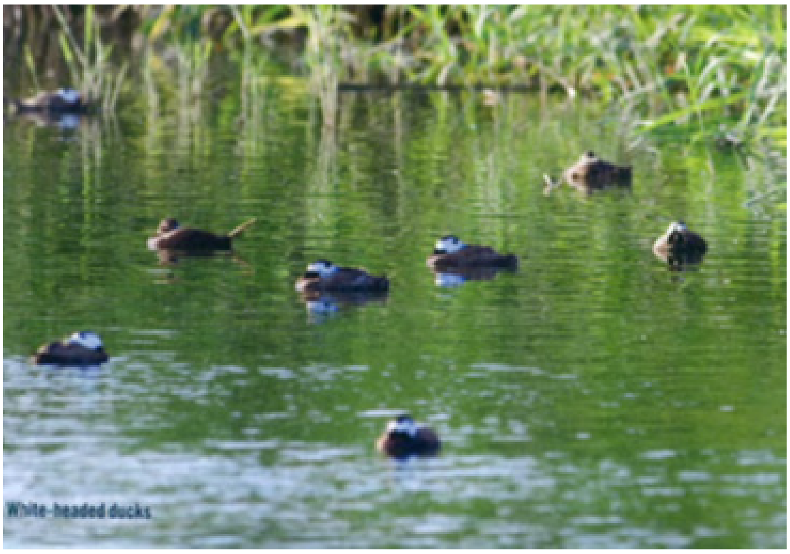
- **Discharge monitoring:**

  Each waste water treatment plant has been established with continuous monitoring of inputs and outputs. This helps monitor discharge to sewers by industries as well as effluent discharge to the river. The monitoring as well as the operation and maintenance of the plants are funded by the Waste Water Reclamation Levy

**Key Outcomes**

- 100 000 000m3/year of wastewater return flows that were previously unusable now treated and made available.
- Ability to meet 6% of irrigation demand.
- Connection of 99% of urban areas to sewers.
- Substantial increase in river water quality; reduction in Biological Oxygen Demand (BOD) by 95%.
- Cost recovery achieved for long term operation of treatment works.
- Negligible discharge of untreated industrial waste to public sewers.
- Compliance with the European Union Urban Wastewater Treatment Directive.
  - An improvement in the river and near-river environment for the people of Murcia
  - Wetlands recovery: two of the largest lagoons are now included in Ramsar Convention list of Wetlands of International Importance




*The Segura River of Spain has been named the winner of the International RiverFoundation's 2016 European Riverprize.*

## 5.37. ERSAR – PORTUGUESE REGULATION AUTHORITY FOR THE DRINKING WATER SUPPLY SERVICES, URBAN WASTEWATER MANAGEMENT SERVICES

Public water supply, urban wastewater management and municipal waste management are public services essential to the well-being, public health and collective security of the populations and economic activities, as well as to environment protection. These services must respect the principles of universal access, uninterrupted and high quality of service and efficient and affordable prices.

ERSAR intends to protect consumers' rights and to ensure the economic sustainability of the municipal and regional water (and waste) utilities. This way, ERSAR aims to promote regulation as a modern tool for State intervention in these essential economic activities, with a view to setting high performance standards and defending public interest.

ERSAR must assure two distinct, although complementary duties: regulation authority for the drinking water supply services, urban wastewater management services and municipal waste management services; and National authority for drinking water quality.

Concerning the first duty, ERSAR, aims to ensure the quality of the services rendered by drinking water supply systems and municipal waste systems, supervising the creation, execution, management and operation of those systems. ERSAR also ensures the stability of the sector and the financial sustainability of these systems. As a regulator, ERSAR acts over all 500 operators of the water and waste sector. In 2003, ERSAR was nominated the national authority for drinking water quality. Currently, the regulation of drinking water quality includes all 400 drinking water supply operators. ERSAR annually approves the water quality control programs that each managing entity is obliged to prepare, monitors the reliability of the laboratory results in coordination with the Portuguese Accreditation Institute and supervises the entities that manage the public supply systems to verify if all the requirements of the legislation are fulfilled. The Portuguese regulator also works with health authorities to resolve water quality problems that may arise.

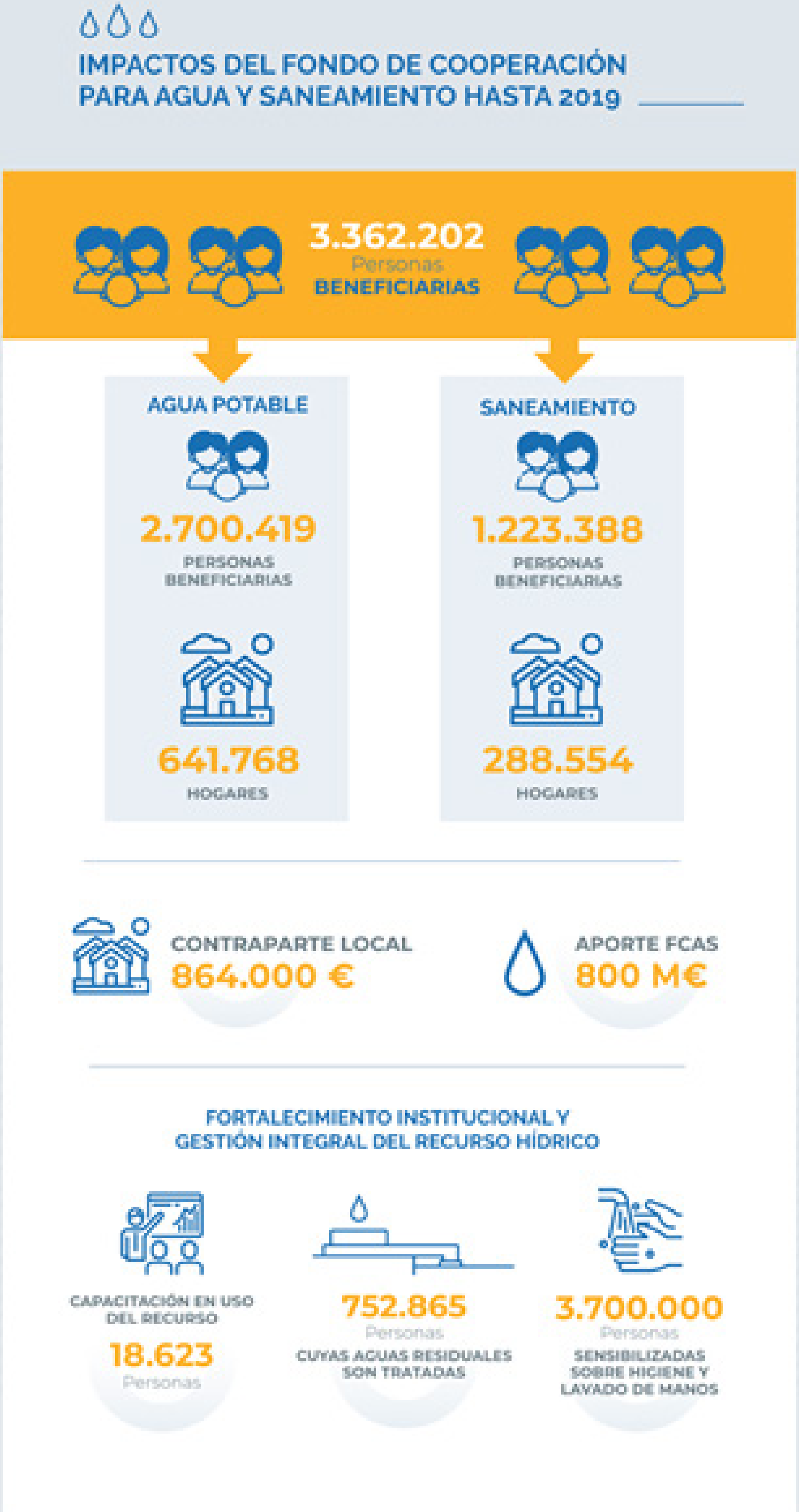
The ERSAR structure includes a board of Directors, several departments, an Advisory Board and a Statutory Auditor. The board of Directors decide upon the strategy and daily actions, as well as the general direction of each department.

## 5.38. THE SPANISH WATER AND SANITATION COOPERATION FUND (FCAS)

The Cooperation Fund for Water and Sanitation Fund (FCAS) is an instrument of Spanish Cooperation that develops programs of institutional strengthening, community development and promotion of water and sanitation services in 18 countries of Latin America and the Caribbean. Interventions focus on rural and peri-urban areas, with the aim of reducing pockets of poverty and inequality.

It promotes a total portfolio of 1,665 million euros (of which 801 are donations from Spain) focused on the effective fulfillment of the human rights to water and sanitation and the UN Sustainable Development Goals. It develops 81 projects and its work has benefited more than 3.3 million people to date. During the COVID19 health crisis, it has also adapted its awareness campaigns around these two issues and promoted hygiene measures in vulnerable neighbourhoods and rural areas.

The Fund, in whose application the work of the engineers of the Spanish Agency for International Cooperation for Development (AECID) and local public bodies, who lead and execute the interventions, has been fundamental. The Fund’s hallmarks are gender, integrated water resources management, environmental protection and cultural diversity.


IMPACTOS DEL FONDO DE COOPERACIÓN
PARA AGUA Y SANEAMIENTO HASTA 2019
3.362.202
Personas
BENEFICIARIAS
AGUA POTABLE
2.700.419
PERSONAS BENEFICIARIAS
641.768
HOGARES
SANEAMIENTO
1.223.388
PERSONAS BENEFICIARIAS
288.554
HOGARES
CONTRAPARTE LOCAL
864.000 €
APORTE FCAS
800 M€
FORTALECIMIENTO INSTITUCIONAL Y
GESTIÓN INTEGRAL DEL RECURSO HÍDRICO
CAPACITACIÓN EN USO DEL RECURSO
18.623
Personas
752.865
Personas
CUYAS AGUAS RESIDUALES SON TRATADAS
3.700.000
Personas
SENSIBILIZADAS SOBRE HIGIENE Y LAVADO DE MANOS

## THE WORK OF THE FUND IN HAITÍ

Haiti is one of the countries with the lowest human development index in the region and with enormous challenges.

The lack of safe drinking water and sanitation in Haiti is responsible for a large number of diseases such as diarrhoea, typhoid fever and cholera. One of the main problems in the area of water and sanitation is the lack of human resources and capacity of public operators to manage these basic services. The public sector is in the midst of institutional reform to improve the management and efficiency of drinking water and sanitation services.

In order to improve the quality and expand the coverage of water services, Haiti has undertaken a profound reform in the water and sanitation sector in which the AECID, through the Fund, plays a key role. The reform, which will regulate and organize these services, has as one of the main objectives to involve the population at all levels and strengthen the institutions responsible for managing water.

In terms of drinking water and sanitation. Haiti's portfolio is the most important in the FCAS, with an active bilateral program and four multi-bilateral programs already completed, and with a budget exceeding 119 million euros in grants. Apart from the civil works component, with great weight from the budgetary point of view, the FCAS develops actions to strengthen the institutional strengthening of the National Directorate of Drinking Water and Sanitation (DINEPA) and its decentralized agencies.

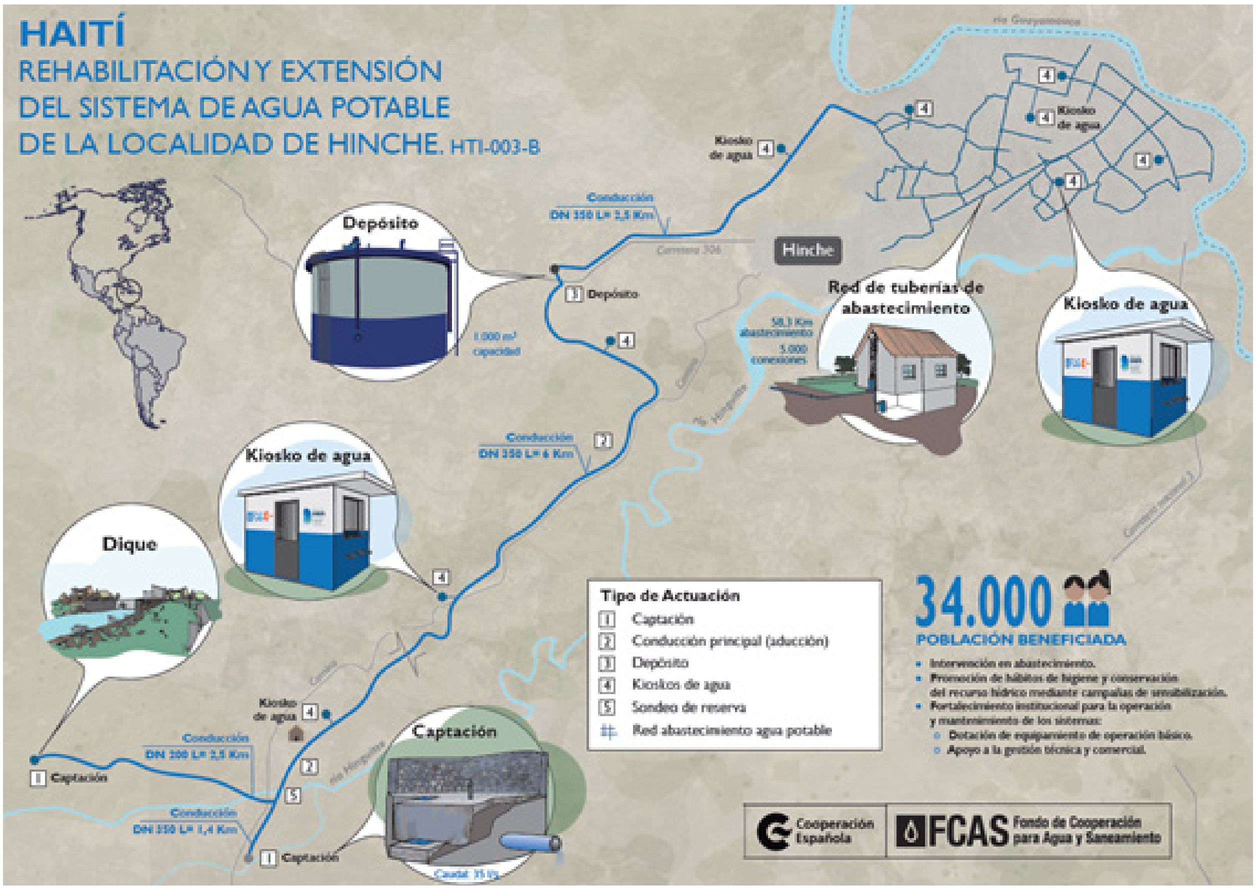
The overall objective of the Fund's five programmes in Haiti (four of which have now been completed) is to contribute in a sustainable manner to increase the haitian population's access to appropriate, equitable and accessible drinking water and sanitation services.

Two specific objectives are complementary and inseparable for the achievement of the general objective: to support the implementation of the reform of the water and sanitation sector in Haiti, strengthening the capacities of the State to regulate and develop the institutional sector and infrastructures and to allow the decentralization of the sector's operations.

**1. Institutional strengthening and improvement of operational capacity.**

(a) Enhancing the capacities of DINEPA in terms of management, control and supervision in the drinking water and sanitation sector.

(b) To carry out decentralization at both the physical and operational levels.




**2. Planning and execution of investments and infrastructure.**

(a) Investment plan

(b) Implementation of the necessary primary drinking water and sanitation infrastructures throughout the national territory

The number of beneficiaries after the end of the programmes will be 1.2 million throughout the country, this figure includes people with improved access to water and sanitation, water or sanitation thanks to the activities carried out by the programme in intermediate and rural cities mainly, as well as in the capital.

# 6 Recomendations and Conclusions

**It is a commonplace, but is important to repeat it, that water is a renewable resource indispensable to life, but scarce, asymmetrical and irregularly distributed in time and space,** being an economic asset with non-consensual value and price among users. In addition, water management is highly complex, in technical, economic, environmental, social, but above all and ultimately, political terms.

The epidemiological context of the COVID-19 pandemic has resulted in the lockdown of entire cities and the social isolation of billions of people, as well as the closure of vital economic activities. Consequently, civil society has recognized the relevance and value of clean water, safe hygiene and dignified sanitation to protect public health. Never before has the message about the importance of frequent and correct handwashing been so pronounced. The focus on WASH in containing the spread of the pandemic is unprecedented, particularly among the most vulnerable communities that do not have ready access to clean water.

Clean water is at the heart of any public health policy and an integral part of sustainable development. Governments and policy-makers should take urgent action to accelerate the realization of SDG 6 and solve the problem of inaccessibility to clean water which creates vicious cycles of poverty, inequality, food shortage and forced migration, particularly in less developed countries.

Climate change affect us globally and, regardless of our efforts to mitigate it, will aggravate the frequency and duration of droughts, often in the poorer areas of the World. Because of decreasing water availability, but also due to increased water use, pressures on available freshwater resources will continue to grow everywhere. The amount of freshwater used on Earth has increased twice in about 30 years and the growth in the use of freshwater resources has increased twice as fast as population growth.

**Cities are and will be particularly critical while addressing SDG 6.** Half of the world's population now lives in urban areas, but by 2050 almost 70% of the population will live in an urban environment. This human concentration will pose major challenges for supply and sanitation services.

The traditional models of urban supply services, strongly centralized and linear, do not distinguish levels of water quality appropriate for different uses, producing high quality drinking water to be used in indiscriminate uses. Concerning sanitation, about half of the world population still does not have an adequate solution and it is unlikely that current public systems, in which solids are carried by water, will ever be applicable in areas that are not yet served, mostly in the peripheries of informal urbanization of large cities in developing countries.

In order to guarantee enough freshwater to produce the necessary food for the growing and higher income population and to produce and distribute the necessary goods and services, while maintaining healthy ecosystems, it will be essential to pursue objectives such as “more crop per drop”, “more jobs per drop”, “better environment per drop” and “improved nutrition per drop”. However, the efforts made in pursuit of these objectives were not sufficient to guarantee the satisfaction of freshwater needs, with many examples of inefficient use remaining, only possible due to the low water prices.

**Clearly, the solutions of the past will not be enough to guarantee a desirable future, without scarcity and limitations in access to freshwater, with less pollution and with higher quality water-related ecosystems, finally aiming at reaching the SDG 6 targets.**

In a possible global scenario of a doubling world population in the coming decades, radical changes are needed that, with regard to water and for survival imperative, cannot be based on business as usual.

**Despite all the problems, we have reasons to be optimistic about the future of water in the World towards the achievement of the SDG 6 targets.**

Anticipated global water challenges related to the impacts of increasing water pollution and climate change need to be addressed, while benefiting from advances in science, technology and innovation in areas such as hydro-environmental models, decision support systems, microelectronics, nanotechnology, fine chemicals, biotechnology and information technology. There are technical solutions to make any quantity of water available, of any quality, at any time and in any place, although its widespread application is limited by the situations of poverty that, unfortunately, remain.

**Reuse and desalination already make it possible to obtain drinking water at very reasonable prices, which will tend to drop substantially in coming years,** due to the reduction in the cost of energy and the increase in the efficiency of the efficiency of the treatment processes. Agriculture could be possible in arid areas and there will be more and more circular economy solutions, which will imply closing, progressively but inevitably, the urban and industrial water cycles.

**There are examples of full-scale application of direct reuse of urban wastewater,** which has long been done in space stations where price is not a decisive factor, but also in Namibia and Singapore, as presented in this report.

**Public acceptance, in these and other cases, was not easy to achieve**, having required a long communication process until confidence levels were established regarding the use of this freshwater source. In reality, indirect reuse is the current practice in most supply systems that capture freshwater in natural systems, where effluents were previously discharged, and existing water treatment plants are not as efficient as those created for direct reuse. in the removal of persistent and complex pollutants, such as antibiotics and other medications.

Bearing in mind that salt water represents 97% of all water resources on the planet, the use of desalinated water can contribute decisively to increase freshwater resources at areas near the coast. **In Israel, desalination and the infrastructure and organization of reuse make it possible to obtain water from "new origins" at less than 50 eurocents per cubic meter.**

**The frequent use of these technologies will require a profound change,** being certain that for the developed regions, already served with modern infrastructures, with relatively low and accessible freshwater costs, the future will most likely be business as usual, with a gradual improvement of existing engineering technologies and solutions. In particular, the most frequent use of desalination and reuse will not happen as long as the price of water captured from natural systems is very low.

In urban supply systems, in addition to the use of new water sources, future approaches will include separate networks with different qualities of water depending on their use. In fact, **only about 1 to 2% of the water we use needs to be potable, so the existence of separate systems would reduce the treatment levels for most of the water we use on a daily basis.** The widespread use of this approach will imply the resizing of building and public systems, something disruptive in the years to come.

**The use of separate networks,** also including wastewater and its reuse, may also operate at the scale of housing, or communities. In low-density areas, more or less autonomous houses may be justified. As for sanitation, dry toilets may also be used, with incineration or composting, since it is much easier to reuse shower water and washing clothes and dishes if the sanitary sewer is previously separated.

**We will have to continue the efficient use of freshwater in all activities,** namely in agriculture, ensuring the best use of the freshwater resources we collect in natural systems. In agricultural systems, adapting crops to available freshwater at a fair price, judicious species selection and precision farming will have to make their way in the short term. It will also be

When the COVID-19 pandemic ends, which will leave a trail of deaths, bankruptcies, unemployment and reconversions unprecedented for decades everywhere, we will be confronted again with a potentially much more serious reality: climate change and its global consequences.

Certainly, humanity will have the sufficient collective intelligence to avoid a global catastrophe. **With regard to water, fortunately, we have solutions already available and increasingly economically viable, making their potential use much more widespread while targeting SDG.** If we are unfortunate that water scarcity gets worse, we know at least that these solutions exist and that we depend on ourselves.

As we face the challenges related with SDG6 fulfilment, technological innovation, knowledge management, advanced research and capacity development will generate new tools and approaches, and equally importantly, will accelerate the implementation of existing knowledge and technologies across all countries and regions. WFEO want to contribute to accelerate the journey through this roadmap.

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