SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

The role of engineers in the effort to achieve SDG/6

A White Paper

This White Paper grew out of the discussion in an open space session proposed by the International Association for Hydro-Environment Engineering and Research (IAHR) during the 32nd UN-Water meeting on 29 January 2020 in Rome with the participation of Angelos Findikakis [1], Pierre Kistler [2], Antonio Torres [3], Geraldine Gene [4], Graham Alabaster [5] and Tomas Sancho [7]. Sean Mulligan [1] and Tom Soo [1], who were not present in the UN-Water meeting, also contributed to the development of this paper.

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Purpose

The purpose of this white paper is to provide an overview of the contribution of engineering to the effort to achieve the water-related Sustainable Development Goals (SDGs) of Agenda 2030 and discuss what more they should be doing, including expanding their horizons beyond the confines of their traditional engineering education and the importance of embracing a human rights-based approach. In addition, it explores how the modern paradigm of engineering, which inherently integrates nature-based approaches, contributes and enables national stakeholders to achieve the SDGs through gender-responsive, human rights-based approaches.

The Sustainable Development Goals (SDGs) of Agenda 2030 are based on findings from the natural and social sciences and other fields regarding the implementation of necessary changes in order to ensure the survival and prosperity of all people and all forms of life on the planet. The SDGs are underpinned by several human rights principles including the principles of universality and indivisibility, participation and inclusion, equity and non-discrimination, and accountability and rule of law. These principles form the basis of a human rights-based approach.

The development of the science of hydrology as a separate field of scientific enquiry in early 20th century provided practical knowledge and information to societal needs in the context of water transport and management, which allowed hydrology and engineering to develop alongside each other.

In the first two thirds of the twentieth century, engineering seemed to be the solution to all water problems through the construction of large infrastructure projects to continuously increase the supply of what perceived then as an unlimited resource. In rural areas the emphasis on supply augmentation continued for much of the twentieth century. Despite the positive societal benefits of water infrastructure projects, many had also ecological consequences, such as, for example, large hydroelectric projects[1].

While substantial progress has been made in increasing access to clean drinking water and sanitation, billions of people –mostly in rural areas– still lack these basic services. Worldwide, 1 in 3 people do not have access to safe drinking water, and 2 out of 5 people do not have a basic hand-washing facility with soap and water.

Water engineering is multidisciplinary. Historically, civil engineers had a prominent role in water resources development, but other engineering disciplines have progressively contributed more and more to dealing with water issues. This includes, but not limited to, mechanical engineers working on hydraulic machinery and other equipment; chemical engineers supporting different aspects of water and wastewater treatment systems; agricultural engineers improving water use efficiency in irrigation; electrical engineers working on energy production and distribution; electronic and information technology engineers supporting precision agriculture, sensors, metering, and big data processing; and environmental engineers working to assess and minimize the impact of projects on the environment.

Even though water resources, engineering and science of hydrology developed essentially in tandem, UNESCO's International Hydrological Decade (IHD; 1965-1974) provided an impetus to begin the global study of water resources available for engineering works. Since the IHD, hydrology has evolved as a transdisciplinary, data-driven science in a remarkably short period of time[2]. The Intergovernmental Hydrological Programme (IHP) strengthened hydrology's scientific and technological bases through the development of methods and techniques, guidelines and training, and the human resources capable of ensuring sustainable water management.

The reassessment of the impact of large water projects, coupled with increased levels of air and water pollution, led to the environmental movement in the 1970s. Later the United Nations launched the International Drinking Water Supply and Sanitation Decade (1981-1990) in parallel with efforts emphasizing appropriate technologies and focusing on "software" (non-engineering) problems[3]. At about the same time there was a shift from continuing supply augmentation to demand management, often tied to more decentralized and community-based management of water resources, the recognition of the economic value of water, and the realization of the great importance of governance in providing basic water services. These new perspectives effectively combined to reduce the role of heavy infrastructure engineering in the water sector, sometimes overlooking its potentially positive contribution. At the end of the Millennium Development Goals (MDG) period (2000-2015) there was more emphasis on the sustainability of the "service" and not just the infrastructure, recognizing that non-functionality rates undermined progress towards the MDGs in many areas. Even though UNESCO had an Engineering Initiative[4] addressing engineering education for sustainable development[5], the role of the engineering discipline has not been perceived as pivotal in realizing the SDGs amongst other disciplines in social sciences and humanities. Moving forward, engineering studies must include social analysis of key issues, among them importantly an analysis of the impacts that proposed solutions may have on gender equity, i.e. they should incorporate a gender-lens into the social analysis in the discipline of engineering. It is also important to ensure equal access to such education for women.

A special challenge in developing a modern curriculum for individual engineering disciplines is finding the right balance between including the range of subjects relevant to sustainability and human rights and at the same time keeping it relevant and recognizable, providing all the required knowledge for practicing the specific branch of engineering.

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As new technologies start supporting water development and services and as we expand the understanding of social and human rights issues around water and sanitation, it is clear that education cannot stop at graduation from school. It must be a continuous lifelong learning process for practicing water professionals, decision makers and managers. Some institutions, professional societies and special capacity building organizations offer continuous education opportunities. Today, the option of blended learning (online and offline) makes it possible to lower costs and facilitate access to water knowledge and information. It should be noted that various professional institutions representing engineers, such as the Institution of Civil Engineers, the South African Institution of Civil Engineering, the American Water Works Association, the International Association of Hydro-Environment Engineering and Research, the World Council of Civil Engineers and the American Society of Civil Engineers, have adapted and changed with the times to inject innovation and promote best practices to serve their members and society whilst aligning themselves to global agreements and development goals like the SDG's.

Looking beyond the water and sanitation for all SDG 6, 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 4 (Target 4.3, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university), SDG 5 (achieving gender equality and empower all women and girls), 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. Engineers working on such problems must recognize that to address these issues must expand their thinking beyond strictly technical solutions, factor in more prominently social aspects (e.g. gender-sensitive planning, human-rights based approach, and leaving-no-one-behind thinking) and appreciate the importance of looking beyond traditional "grey" solutions by adopting nature-based solutions.

Nonetheless, there has been a significant change in the education and thinking among upcoming engineers. It is no accident that most Civil Engineering Departments in the United States changed their name to Civil and Environmental Engineering where their curriculum was expanded to cover a broad range of subjects, mostly on wastewater treatment and solid waste management, but also other environmental issues, and later to introduce the concept of sustainable development in teaching engineering design. However, the emphasis on environmental issues in engineering education seems to be placing most of its emphasis on the natural environment, often overlooking key aspects of the human environment such as population growth and climate change resilience that must be factored into design. Despite such limitations, today's graduating engineers are aware of the need for a multidisciplinary approach to problem solving.

It is important that engineering education emphasizes the multi-dimensional nature of sustainability[6]. This should include awareness of social, human-rights and gender equity issues affecting or affected by engineered solutions supporting the SDGs. These solutions must embed gender-responsive human rights-based considerations. In addition, engineering curricula should emphasize the interdisciplinary nature of most problems and give a prominent position to nature-based 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 role of SDG 6 is to significantly accelerate this progress through a number of specific targets.

The objective of this paper is therefore to better highlight the contributions of engineering in the endeavor to achieve SDG6 and to dispel some of the misconceptions about how today's engineers think and work.

This paper aims also in assisting to mobilize and empower more engineers, including women and others from diverse backgrounds and experiences, in the effort to achieve SDG 6 by pointing out where and how they could contribute going into the future.

Specific contributions to SDG/6

Water engineering is a multidisciplinary profession, involving the combined skill and collaboration of many subdisciplines of engineering as outlined in Figure 1. To better understand how these engineers can contribute to achieving SDG 6, which aims at ensuring the availability and sustainable management of water and sanitation for all, designs need to be (locally) accessible, applicable, appropriate, and affordable. The key individual targets are shown schematically in Figure 1 and are outlined below together with the role engineers play in realizing the goals therein.

Target 6.1
Drinking Water

Target 6.1 sets out to achieve universal and equitable access to safe and affordable drinking water for all. This concerns people living either in non-serviced and degraded parts of urban centers, or in rural communities across the globe.

Engineers play a dual role in this process. "Safe" drinking water means the provision of water free from contaminants using treatment approaches that are designed to be effective and robust, as well as affordable. This requires innovative thinking in the design of effective, yet inexpensive treatment technologies. Design needs to include the way maintenance can be done locally (both in terms of availability of spare parts, and training and governance arrangements). The "for all" aspect requires engineers to play major role in providing distribution networks and/or the development of new local water sources, such as groundwater supply, where the share in water is provided in an equitable manner. The challenge for engineers is to design the appropriate and sustainable water infrastructure in each case and find ways to reduce the required capital cost for its construction, without deviating from respecting local customs and traditions.

A replicable and valuable lesson learned from the humanitarian sector is the focus on participatory approaches and community engagement strategies for the design (and construction) of contextualized and appropriate WASH facilities. This modus operandi is further away from the classical engineering practices, which often disregard human-centered designs and approaches, in favor of a more typical contractor form of work. Ensuring access to safe drinking water in rural communities requires different solutions, which can also benefit by applying the principles and methods engineers use at a small scale.

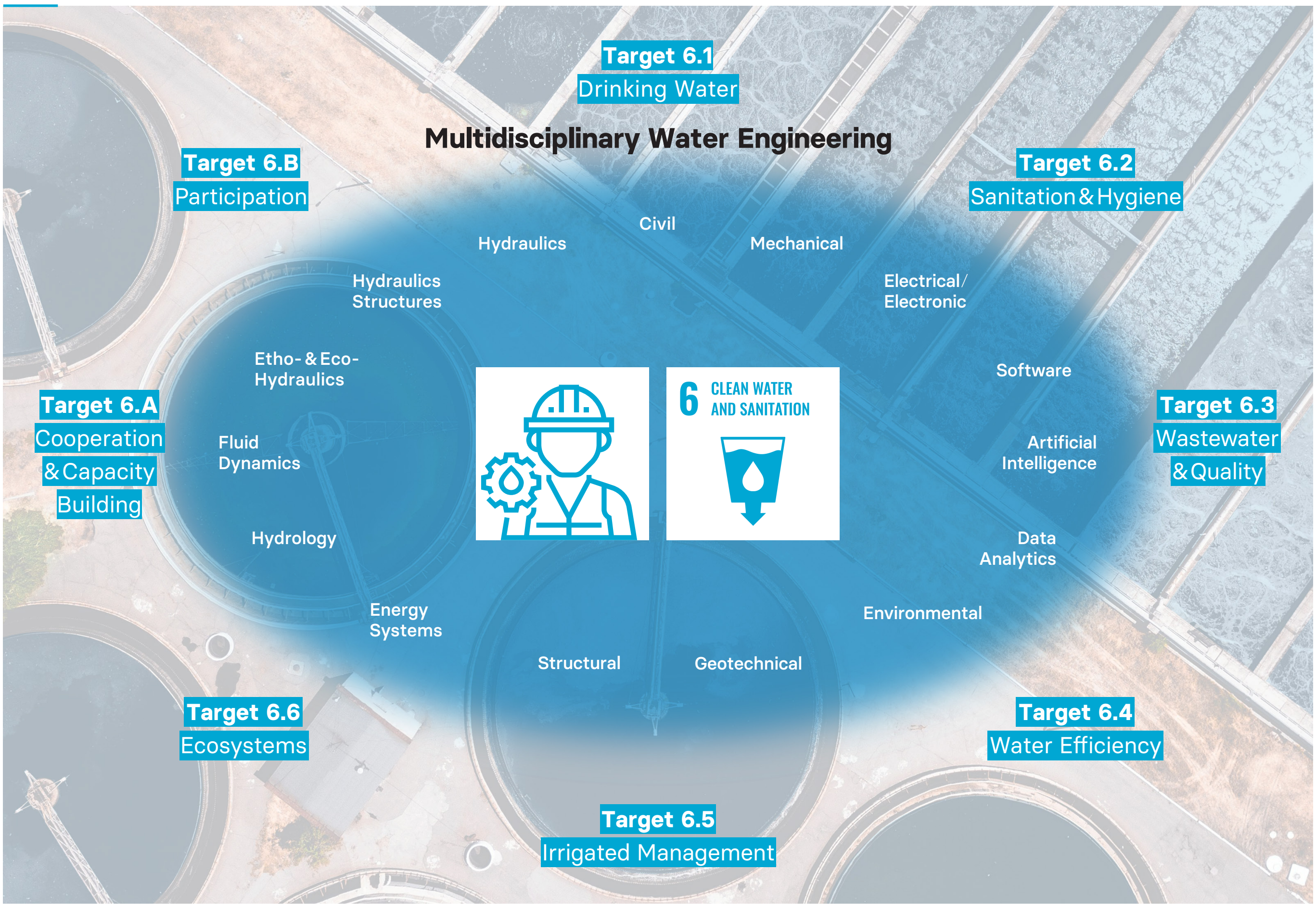

Figure 1 | The role of multidisciplinary engineering in tackling SDG 6 and relevant targets

Sustainable services play also a key role in the life of water infrastructures, and when designing or rehabilitating a water supply system, conditional repair based on the likelihood of future sustainable management should tip the scale towards the most appropriate type of intervention.

Target 6.2
Sanitation and hygiene

The objective of target 6.2 is to ensure that all use safely managed sanitation services, including a handwashing facility with soap and water. Progress towards this and other targets of SDG6 is tracked at the country level. The COVID-19 pandemic has further demonstrated the importance of sanitation, hygiene and adequate access to clean water in the effort to prevent and contain diseases. Sanitation and hygiene are largely underpinned by the engineered provision of clean water as per Target 6.2. It is important to use solutions that represent the best option in different parts of the world, such as, for example, container-based sanitation, and decentralized processing/treatment. The effort to achieve access to adequate and equitable sanitation will also benefit from innovative solutions provided by various engineering disciplines such as the design of new appropriate types of toilets, or creative concepts of the sanitation economy that uses circular, multi-sectoral (including digital solutions), collaborative thinking to the problem of sanitation.

Target 6.3
Wastewater and water quality

In 2017 it was estimated that 56% of all global freshwater withdrawals was released to the environment as wastewater, and that it is likely that over 80% of this is released untreated[7].

The problem is intensified by rainfall, which enters legacy combined sewer overflows consequently increasing the frequency of raw wastewater discharges along with higher volumes of surface contaminated runoffs. Climate change and population growth will further exacerbate the problem.

This target requires reducing water pollution and halving the proportion of untreated wastewater (i.e. reducing untreated wastewater discharges from about 2,200 to 1,100 billion cubic meters per year in 2030) both in developed and developing countries. This will undoubtedly require the involvement of engineers at all aspects of the problem-solution design chain. In recent years, engineers have been engaged in several high-impact solutions such as:

- The design and construction of appropriately scaled wastewater treatment plants (WWTP)
- Retrofit and expansion of existing wastewater treatment plants
- Sustainable urbans drainage schemes
- Combined sewer replacement with separated sewers
- Combined sewer interception structures
- Deep sewer conveyance systems
- Decentralized Wastewater Treatment Systems (DEWATS)
- Nature-based solutions
- Reuse measures

Today, we see the start of the transformation of WWTPs to biofactories, i.e. to resource-producing centers that do not generate waste or impact the environment. Such facilities do not consume fossil energy because they produce their own energy, which is used to support their operation[8], and they transform waste into resources by capturing nutrients that can be used as fertilizers.

Many of these project types emerge in high-income countries adapting to urban development and population growth issues. The challenge will be for engineers to design and deliver affordable alternatives to low-to-middle-income countries through innovative treatment technologies and alternative approaches to infrastructure development using locally sourced equipment and materials. In particular, low carbon footprint and decentralized treatment technologies for smaller populations permitting water reuse will be critical in this context. An example of such an effort is the EU funded Innoqua project[9] involving 20 international partners that seeks to demonstrate in real conditions a modular decentralized system for water treatment based on locally sourced biological organisms (such as earthworms and zooplankton).

According to the World Health Organization, 2 billion people still do not have basic sanitation facilites such as toilets or letrines.

Target 6.4
Water use and efficiency

This target requires increasing water use efficiency across all sectors to address water scarcity and requires improvements in the design of water conveyance, distribution and processing systems and changes in the use of water in agriculture. In the energy sector, energy efficiency is described as the “first fuel”, where energy not used becomes a source of fuel in its own right. The same applies to water, where water use efficiency, or water sustainably saved, has a similar effect, i.e. increasing supply in a low-cost manner.
Water use efficiency requires innovative, engineering led design thinking to develop novel methods to identify and eliminate leaks, smart water metering to track inefficient usage and water storage approaches such as rainwater harvesting for grey water displacement of potable water use. These approaches will support this endeavor, particularly in high-income countries where water wealth is not entirely appreciated. It is noted also that due to the water-energy nexus, efficient water usage will inherently affect efficient energy use, therefore having a wider impact on SDGs 12 and 13. Engineers can contribute to both the water and the energy side of the nexus by considering also that water inefficiency leads to a vicious cycle, as increased water supply requires more energy use for the operation of the water infrastructure resulting to increased water demand for energy production and so on[10].

Specific ways that engineering can contribute to improving water-use efficiency in include:

- In irrigated agriculture (by far the largest water user, accounting for nearly 70 per cent of all water withdrawals globally, and as much as 90 per cent in some arid countries) by developing for efficient water delivery systems and reducing losses in water conveyance.
- In municipal distribution networks, and in industrial and energy cooling processes by reducing losses.
- In cities and other areas by using Sustainable Drainage Systems (SuDS), encouraging natural recharge of aquifers and implementing nature-based solutions in rivers.
- In the industry and agriculture by using efficiently and safely non-conventional water sources, such as treated wastewater or storm runoff.

The implementation and many of these approaches and systems can benefit by the increasing use of artificial intelligence, which can help optimize operations and resource management.

Target 6.5
Integrated Water resources management

Integrated water resources management requires collaboration across several fields, with engineers contributing technical solutions to many of the requirements set by other disciplines. The contribution of engineering is not limited to the design and operation of the water infrastructure (dams and reservoirs, channels, pipelines, water treatment plants), but it extends to water planning and management, and supports good water governance. Engineers often provide the analytical tools for modeling water systems, such as entire river basins, to assess and evaluate alternative options for effective integration of their management in an equitable manner, and in the case of trans-boundary basins taking into account the international treaties signed by the countries that oblige them to respect certain international norms in the integrated management of the resource.

Target 6.6
Water related ecosystems

Ultimately, water related ecosystems underpin the provision of good quality water and therefore must be safeguarded. The protection and restoration of water-related ecosystems requires the evaluation of options with a combination of hydrological models and big data sets often developed and analyzed by engineers. It is worth noting that in many cases, achieving Targets 6.1, 6.2 and 6.3 may have an impact on ecosystems which must be carefully understood, and risk assessed by an environmental engineer. In addition, new fields of engineering are emerging such as ecohydraulics and ethohydraulics to study the effects of natural waterways and hydraulic structures on fish behavior and migration using physical methods and computational fluid dynamics which is crucial to ensure that interventions have minimal impact on existing ecosystems, which goes hand in hand with the principle of sustainability, guiding human rights. Nowadays there is more and more attention for nature-based solutions for the protection and sustained management of natural ecosystems. An all-round professional, i.e. an engineer capable of going beyond construction, is strongly needed if we want to achieve the SDGs.

Target 6.A and B
Cooperation and capacity building and stakeholder participation

International organizations and associations of engineers can contribute significantly to capacity-building support to developing countries in water-and sanitation-related activities and especially in technologies for water treatment and reuse, monitoring, desalination and increased efficiency for different water uses.

Engineers play also an important role in identifying zones of opportunity and monitoring progress towards SDG 6 by collecting data for the agreed indicators and processing and analyzing datasets to provide actionable insights on progress. Engineers should also effectively and clearly communicate the information produced by the data to politicians and government officials to ensure that decision making is data driven. Engineers have the responsibility to explain often complex water issues in easily understood terms and help the general public trust science. It is also the role of professional societies to be vocal about the misrepresentation of facts.

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. For example, the energy supply company (ESCO) approach is being considered as an instrument to help bring capital into the water industry by considering both water and energy use efficiency[11]. Engineers play a crucial role in understanding both energy and water needs to help close the gap between finance and implementation. In particular, this type of cooperation can significantly enhance progress in targets 6.1, 6.2 and 6.3 in low-to-middle-income countries.

Interlinkages with other water related goals and targets

Furthermore, engineering also plays an important role in the implementation of many other goals that are related to water such as those on poverty reduction and equality (SDGs 1, 10, 16) , agriculture (SDG 2), health (SDG 3), education (SDG 4), gender (SDG 5), energy (SDG 7), the economy and infrastructure (SDGs 8 to 12), disaster and climate change and resilience (SDGs 11, 13), and the environment (SDGs 14, 15), and to address the impacts of climate change on water resources and help cope with extreme events such as floods and droughts.

In addition, engineers can help reduce the rate of climate change by, among other things, emphasizing the "green economy", incorporating life-cycle analysis into their work and factoring in environmental externalities into decision making and life-cycle cost analyses. Engineers with various facets are instrumental in assessing and stewarding transitions in a Nexus approach, in particular the Water-Energy-Food Nexus and its variations[12]. The engineering discipline also facilitates international cooperation contributing to the revitalization of global partnerships for sustainable development (SDG 17). Finally, the role of engineering in the implementation of the Sendai Framework and Paris agreement should be highlighted.



Looking ahead

It is clear that the targets set out between now and 2030 are ambitious, but they can be realized with the full involvement of the wider engineering community. This of course will require funding and financing mechanisms to bridge the gap where "for every dollar spent on water and sanitation, on average four dollars are returned in economic benefits, according to World Bank estimates"[13]. The grand solution will also likely involve empowering engineers in government organizations, international research organizations (such as the IAHR), academic and research institutions, civil society and in the private sector to tackle the problem through identifying "hot spots" requiring action, in technology solution provision (as outlined in previous targets) or through education and knowledge exchange. It should also ensure equal access to engineering education, employment and promotion for women in all their diversity. Voluntary programs and campaigns such as Engineers Without Borders will undoubtedly play a significant role as well.

The UN-Water coordination mechanism offers a platform to inform about the many facets of the contribution of engineering in the effort to achieve SDG 6, but also presents an opportunity to the partner organizations to learn what more can they do, or what can they do differently to increase the effectiveness of their contribution.

Among the latter is the need to overcome the tendency of engineers in the past to operate in their own world developing technical solutions that sometimes did not take into consideration the views and concerns of all stakeholders. In this problem-oriented approach, it is important that engineers engage in a dialog with the communities they serve and be responsive by adapting their designs to their needs. The dialog with communities can be facilitated by international organizations or humanitarian agencies, which should step up for a more fruitful engagement with the engineers, having already the knowledge of what is needed at the field level. Mechanisms should be in place to ensure the voice and agency of women to contribute to and be consulted in such community dialogues. Engineers will only be able to contribute meaningfully to the achievement of SDG 6 if they employ a human rights-based approach.

In conclusion, engineering can be viewed as an accelerator in the effort to achieve the objectives of SDG 6.

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