Global Knowledge Platform

Sustainable Water and Energy Solutions: Addressing Critical Services during the COVID-19 World Crisis and Beyond

Scoping Paper

July 2020

SUSTAINABLE WATER & ENERGY SOLUTIONS NETWORK

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MEMBERS OF SUSTAINABLE WATER AND ENERGY SOLUTIONS NETWORK

Ministry Foreign Affairs Tajikistan

Acknowledgements

This document was prepared in support of the Sustainable Water and Energy Solutions Network by the Division for Sustainable Development Goals of the United Nations Department of Economic and Social Affairs. During the initial phase, UN DESA and ITAIPU Binational, leveraging their on-going partnership on "Sustainable Water and Energy Solutions", are jointly providing secretariat services to facilitate operational aspects of the Network, substantively, logistically and administratively. The views expressed in this document do not necessarily reflect those of the United Nations or the organizations mentioned.

Executive Summary

The importance of energy and water and their strong interdependence have become more evident during the COVID-19 world crisis of 2020. Without the critical services of water and energy, the full spectrum of health services could not be implemented. A catastrophic situation could occur anywhere if these services were to be disrupted even for a short period of time during a pandemic. In light of the terrible consequences resulting from the COVID-19 pandemic, sustainable water and energy solutions are viewed as a necessary response during this world health crisis and beyond.

The Sustainable Water and Energy Solutions Network is developing a Global Knowledge Platform with a view to collect information on activities, case studies and systems being implemented or planned using an integrated approach to water and energy challenges. It is expected to gather relevant data and facilitate information exchange worldwide. The Platform will help to disseminate knowledge about the synergies that can be realized when integrated approaches are used to tackle water and energy services, including during world health crises.

The main objective of this scoping paper is to provide preliminary recommendations for the possible scope, priority content and structure of the envisioned Global Knowledge Platform. The scoping paper presents a summary review of efforts being undertaken around the world at international, regional and national levels on integrated and efficient approaches to water and energy. While there has been significant progress at all levels to address the water-energy interlinkage, there also remain considerable asymmetries and gaps. In many cases relevant data are missing, and available modelling and analytical tools still have limited use, especially in developing countries. The scoping paper points to the need for a coordinated global effort to further advance national policies and institutional arrangements to promote integrated sustainable water and energy solutions.

The scope of the Global Knowledge Platform on Sustainable Water and Energy Solutions could include the following main categories: coordinated global efforts and international cooperation; national policies, regulatory considerations and institutional arrangements; asymmetries; data issues; modelling and analytical tools; gaps; means of implementation (financing, capacity development and technology transfer); and technological areas and innovative systems. The Knowledge Platform could be structured following these categories allowing for a very wide range of areas and subjects for users to select in their searches. The priority content for the Knowledge Platform could be about the emerging potential core of integrated systems and innovative technologies supporting sustainable water and energy solutions that offer the best opportunities to realize synergies and efficiencies.

1. Background

Water and energy are key preconditions for human life on earth, and fundamental for economic and social development. Most forms of energy generation need water, whether for powering turbines, transferring heat, cooling machines, or growing biomass and fuel crops on irrigated land. At the same time, all modern systems that provide water for drinking, industrial production, or irrigation, and all systems that treat wastewater for reuse depend on energy for pumping, transport and processing.

With continuing population growth, further expansion of industrialized and developing economies, and plans for accelerated provision of access to water, energy, and sanitation for the urban and rural poor, global needs for water and energy are projected to continue to grow rapidly. More efficient water and energy systems will be needed for enabling sustainable development. The needs for additional sustainable water and energy supplies are high in most developing countries, particularly in the least developed countries.

The interdependency of water and energy has significant implications for both water and energy security. Understanding the interlinkages at global, regional, national, and local levels is crucial to anticipate future stress points, formulate rational policies, select appropriate technologies, manage risks, realize valuable synergies, and prevent eventual conflicts.

The importance of energy and water and their strong interdependence have become more evident during the COVID-19 world crisis of 2020. These are key services necessary to ensure the health and safety of the world population especially during a pandemic. Electricity is particularly critical to run health equipment and facilities and for refrigeration of medicines and vaccines. It is also indispensable for knowledge dissemination and public emergency preparedness. Clean water is essential for drinking, hand washing, sanitation and for food security. The interdependent relationship between water and energy services is considered a major factor and priority for the effective planning and response to pandemics. (NIAC, 2007) Integrated water and energy solutions represent an innovative approach that allows the achievement of synergies for the effective management of these basic services. International cooperation for implementation of integrated water and energy solutions is necessary to support the health and safety of the global population. Private intervention and actions could also play an important role in supporting public efforts. Potential sustainable water and energy solutions and their positive impacts on health services could ensure a more effective and robust response to health crises and subsequently a more resilient and better economic recovery.

Integrating climate change and pandemic concerns into policy and project decision activities makes addressing the water and energy future more complex and challenging. However, innovative water and energy integrated systems represent valuable opportunities for mitigation and adaptation to climate change and for ensuring effective availability of these critical services during the COVID-19 world crisis and beyond.

Water and energy: Goals of the UN 2030 Agenda for Sustainable Development

In September 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development. The 2030 Agenda sets out 17 Sustainable

Development Goals (SDGs) and a total of 169 related targets designed to stimulate concrete actions over a 15-year period. The 2030 Agenda provides the framework for a comprehensive plan of action that, if implemented with vigour and without delay, could help eradicate poverty and ensure sustainable development. The 2030 Agenda recognizes the central role that water and energy play in advancing sustainable development by having dedicated SDGs for water (SDG 6) and for energy (SDG 7). Progress on SDG 6 and SDG 7 will need to take into account SDG 13, which calls for urgent action to combat climate change and its impacts, as well as other SDGs. There are also major implications that will need to be considered related to the reliability of water and energy services during world health crises such as the COVID-19 pandemic.

2. The Sustainable Water and Energy Solutions Network and its Global Knowledge Platform

Historically, most public and private sector investment decisions on the development use of water or energy resources or their infrastructures are typically taken independently, focusing solely on immediate needs of the project or respective business sector. Business decisions are also guided primarily by concerns related to immediate or near-term financial viability, sometimes without taking external factors or long-term effects into account such as climate change.

Recognizing the need to address the interlinkages between water and energy in a more systematic manner, the UN Department of Economic and Social Affairs (UN DESA) and Itaipu Binacional jointly launched a new sustainable development initiative entitled “Sustainable Water and Energy Solutions Network” in December 2018. UN DESA serves as the Secretariat to the intergovernmental consultations on sustainable development at the United Nations, including the High-level Political Forum (HLPF) on Sustainable Development. Itaipu is the Bi-National organization established by the Governments of Brazil and Paraguay to harness the hydropower of the Paraná River. With a total power generation of 2.6 billion megawatt-hours since 1984, the Itaipu Hydropower Plant is the world’s largest generator of hydropower (Itaipu, 2018a) (Itaipu, 2018b).

As of May 2020, fourteen additional partners organizations had already joined the Sustainable Water and Energy Solutions Network including: UNFCCC, UNECE, UNESCWA, UN-HABITAT, Ministry of Ecological Transition Spain, Ministry of Foreign Affairs Tajikistan, IRENA, Asazgua (Guatemala), National Water Agency Brazil, TERI School of Advanced Studies (India), SINTEF (Norway), IIASA, International Hydropower Association and World Energy Council. Several more members are expected to commit to the Network and its mission in the near future.

Objectives of the Network

The goal of this multi-stakeholder Network is to provide a global platform for all stakeholders to enhance capacities and signal their high-level commitment to the integrated approach to SDG 6 and SDG 7 in support of the SDGs achievement. As laid out by the founding members of the Network, the specific objectives are to:

- Share practices, experiences and quality data on the water-energy interlinkages and their contributions to other SDGs.

- Mobilise and scale up multi-stakeholder action aimed at stimulating integrated water-energy response addressing cross cultural in other developing countries

- Enhance advocacy, communication and outreach to help countries conduct evidence-based dialogues and facilitate broad-based implementation of SDG 6 and SDG 7, while simultaneously advancing SDG 13 and other SDGs.

- Strengthen capacity building with a focus on planning, designing, implementing and monitoring of policies, regulations, business models and investment to effectively manage the water-energy interlinkages and their implementation on other SDGs

In light of the terrible consequences resulting from the COVID-19 pandemic, sustainable water and energy solutions are viewed as a necessary response during this world health crisis and beyond, particularly in those nations and communities where benefits from integrated water and energy solutions could be critical to health services and to save lives. Therefore, the Network will concentrate efforts in supporting the world community in its search for transformative pathways to achieve universal access to these critical services to promote the develop and availability of affordable and efficient integrated systems that maximize the reliability of these services.

The Global Knowledge Platform on Sustainable Water and Energy Solutions

In addition to the previously mentioned objectives, the Network is developing a Global Knowledge Platform on Sustainable Water and Energy Solutions. This online Global Platform is necessary to collect, store and classify data, statistics, modelling techniques, and information on activities, case studies and practices being implemented or planned using an integrated approach to water and energy challenges.

The Platform will provide a valuable mechanism for the exchange and dissemination of knowledge and experiences related to integrated approaches to sustainable water, energy and sanitation in a world that could be affected by pandemics such as the COVID-19. The Platform will help to disseminate knowledge about the synergies that can be realized when integrated approaches are used to tackle these critical services including during world health crises. Users will also have the opportunity to learn and discuss innovative technological systems designed to promote efficient and effective use of available resources for a more resilient recovery to COVID-19.

3. Addressing Critical Services during the COVID-19 World Crisis and Beyond

The COVID-19 pandemic in record time has brought immense tragedy reflected by the large number of people who have died or have become seriously ill and the devastating impacts to the world economy. The crisis has made evident to everyone the importance of high-capacity, robust and reliable health systems, programmes, medical equipment and infrastructures as well as the availability of relevant medications, materials and personal protective equipment for health professionals and for the public in general. Additionally, the negative impacts from the pandemic have brought to the top of the agenda of policymakers and decisionmakers the need for comprehensive contingency plans and preparations for the world to be able to successfully confront this type of crisis now and in the future.

Behind reliable health programmes, there are a number of critical services, sometimes taken for granted, without which the full spectrum of health services could not be executed. These critical services include water and energy. A catastrophic situation of a monumental dimension could occur if these services were to be disrupted anywhere even for a short period of time during a pandemic.

Water is essential for washing hands, for medical procedures, for medicines and for adequate hygiene and sanitation. Additionally, water is indispensable for many energy systems such as electric generating power plants. Energy is needed for lighting, for refrigeration, for space heating and cooling, and for communication. Energy is also necessary for water supply, distribution and treatment and for disposal and recycling. Therefore, the availability and reliability of water services are closely related to the availability and reliability of energy services and vice-versa. And without energy and water services not only the health services can be compromised but also the food chain.

As the pandemic progresses around the world and if the crisis continues over many months or years, water and energy services could be at risk. As a matter of fact, there is little information on the impacts that an extended world health crisis could have on critical services such as water and energy. The essential workforce in water and energy utilities could be disrupted as well as a number of essential inputs needed to either generate electricity or to treat water. Recurrent catastrophic events such as droughts and hurricanes could happen concurrently with COVID-19 type of crises affecting water and energy services and making the situation even worse. Some of these events are becoming more intense and frequent in different world regions as a result of climate change. Although critical water and energy industries plan for a variety of contingencies, including pandemics, COVID-19 is revealing the vulnerabilities of multiple contingency scenarios even in developed countries. Modifying contingency plans for severe weather responses may be necessary, given that the baseline assumptions of these plans do not reflect the human and other capacity constraints imposed by pandemic conditions.

The effective management of the interdependence between water and energy is very important and critical for the world population particularly during a world health crisis. The world reliance on water and energy has never been more evident than during the COVID19 world crisis in 2020. The sustainability of systems supporting world health services, the world economy and the population at large should be based on maximizing resilience and efficiency of water and energy resources. Therefore, sustainable water and energy solutions represent a necessary response to the COVID19 crisis.

There is a vast potential for improvement in the way the world harnesses water and energy resources. Integrated water-energy systems could provide the added efficiency and the added access necessary to ensure the safety and well-being of the world population.

Scoping Paper Objective

The main objective of this scoping paper is to provide preliminary recommendations for the scope, structure and priority content for the envisioned Global Knowledge Platform of the Sustainable Water and Energy Solutions Network. The recommendations represent the result of a review of relevant efforts on integrated approaches to water and energy in decision making and in the implementation of projects and programmes for sustainable development taking into consideration climate change. A compendium of twenty selected case studies is included as an annex that serves to exemplify activities and experiences using integrated approaches to water and energy.

4. Brief review of efforts on integrated approaches to water and energy

The relevant review performed for this Scoping Paper confirmed the global consensus that water and energy are strongly interlinked and highly interdependent and both are key factors in pursuing sustainable development and climate change objectives. Looking into the future, water and energy demand will continue increasing due to expected population growth and progress towards sustainable development. The global discussion on an integrated approach to water and energy has intensified after 2011. Since then, many efforts have been initiated and have increased. These efforts cover many communities, cities and countries and all the world regions including developing and developed regions. Major energy and water international organizations are playing an important role in creating awareness and advancing research and analysis on this subject. As expected, a large number of efforts are happening in countries or regions with limited water and/or energy resources and where expected economic and population growths in the future imply a major increase in the demand for clean water and modern energy services. Furthermore, the COVID-19 crisis in 2020 has brought to the attention of policymakers the importance of reliable water and energy services and their interdependence and the role that integrated sustainable water and energy solutions could play during world health crises allowing synergies and efficiencies that can be critical to save lives.

The experiences and activities related to the water-energy nexus are extensive and cover all sectors of the economy including the service, residential, commercial, industrial, manufacturing, agriculture, and transport sectors. Examples are found that show the active and direct involvement of all stakeholders including the public and private sectors and partnerships.

Many innovative approaches are being tried to address the water-energy nexus. Some of these integrated systems are still in the developing stage and will need demonstration and commercialization. Nevertheless, a potential core of integrated systems and technologies is emerging that offer the best opportunities to realize synergies and efficiencies and that could more effectively support the global goals on sustainable development and climate change. These promising systems focus on specific areas of both water and energy cycles that could benefit the most from an integrated approach. New renewable energy technologies that require less water per unit of energy produced represent an advantage over water-intensive energy technologies including fossil fuels systems, and therefore are favoured given the overall global goals and concerns about climate change and the need for efficient water-energy systems in response to the COVI-19 crisis. Water processing and supply systems that use renewable energy or that have major potential for enhanced energy efficiency are also favoured. Unconventional water and energy recovery are other promising options.

These integrated solutions represent a rich spectrum of opportunities for a better recovery and a more resilient world after COVID-19. Returning to the path of independent and inefficient solutions for water and energy should not be an option. Many synergies and efficiencies can be realized for the wellbeing and safety of future generations. The crisis can lead to the transformational changes needed to build more equitable societies equipped with more integrated, efficient and resilient water and energy services based on policy frameworks that support SDG 6 and SDG 7. A new world order points towards water and energy services becoming an essential part of the social protection systems and these services should not be subject to any type of risk during world health crises.

Harnessing political enthusiasm is necessary for integrated clean energy and water and related infrastructure to be supported by new lasting regulatory reforms. This represents an opportunity to turn the COVID-19 world crisis into a transformative moment to induce sustainable and integrated services on water, energy and sanitation for all. This includes accelerating the development and implementation of sustainable water and energy solutions at a universal level and ensuring that no one is left behind. The world needs integrated water and energy solutions with sufficient surge or redundant capacity to withstand catastrophic events such as world health crises.

Efforts at the international level

The international community of experts both on water and on energy has recognized the importance of this integrated approach as evidenced by the large number of research activities and studies published in the last decade. Important international organizations specialized in the issues of water and energy which have conducted relevant activities and are involved in current efforts include: UNESCO/World Water Assessment Programme, the International Energy Agency, the World Bank, the International Institute for Applied Systems Analysis (IIASA), the International Renewable Energy Agency (IRENA), the World Resources Institute (WRI), the UN Economic Commission for Europe (UNECE), among others. Other major research efforts that could be classified at the international level are being conducted by academia with research activities of interest to nations all over the world.

The following paragraphs provide brief summaries of selected examples of relevant efforts at the international level.

UNESCO and the World Water Assessment Programme dedicated the 2014 edition of the *UN World Water Development Report* to a comprehensive study on *Water and Energy*. The report assesses both the energy and the water situations, their interlinkages and data related issues. It includes thematic sections addressing infrastructure, industry, cities, agriculture and ecosystems. It also includes regional analysis and identified responses. The second part of the report presents case studies from five regions (UNESCO, 2014). A follow-up UN World Water Development Report analysing recent trends was published in 2019 (UNESCO, 2019).

The International Energy Agency (IEA) efforts before 2016 had focused on the impact of water availability on different processes of the energy sector and on the energy sector's impact on water quality and quantity. The IEA published a report in 2016 entitled *Water Energy Nexus* as an excerpt of the *World Energy Outlook* (WEO). The report further assesses the nexus by providing a systematic global estimate of the amount of energy used to supply water to consumers. Future energy requirements in water systems such as desalination, wastewater treatment and water distribution are described within the context of two modelling scenarios of the IEA's World Energy Outlook (IEA, 2016a and 2016b). In 2018 IEA published the *Energy, Water and the Sustainable Development Goals*, as an excerpt from the *World Energy Outlook 2018.* The report presents an analysis quantifying the water needs of the energy-related SDGs and the energy required to fulfil SDG 6 on water and the links and synergies between water and energy. The analysis is based on the WEO Sustainable Development Scenario that now includes the water dimension (IEA, 2018b). The IEA published a report in May 2020 summarizing the impacts of the COVID-19 crisis on the global energy demand and CO2 emissions. The report found a major shift towards low-carbon sources of electricity including wind, solar PV, hydropower and nuclear during the COVID-19 crisis. The situation shows the potential that energy efficiency and renewables have as pillars for a possible clean energy transition that could create jobs, enhance economic competitiveness and improve the resilience of energy systems. (IEA, 2020a)

The World Bank conducted an initiative entitled "Thirsty Energy" during the 2014-2018 period in order to address challenges related to energy and water resource planning. The effort consisted of activities at the global and at country levels designed to raise awareness about the water-energy challenges, identify synergies and quantify trade-offs, coordinate decision making and pilot water-smart energy planning tools. The initiative also promoted dialogue among international organizations, governments and the private sector (World Bank, 2018a). The World Bank also published a very relevant report in 2018 entitled *Where the Sun meets Water: Floating Solar Market Report* which describes how this emerging energy-water integrated system works and the potential market, benefits and opportunities in the future. The report mentions the successful implementation of this integrated system in some countries including Malaysia, Japan, and in Montalegre, Portugal where the first-ever hydropower-connected floating solar is already operating (World Bank, 2018d).

The International Institute for Applied Systems Analysis (IIASA) has been leading a major project on Integrated Solutions for Water, Energy and Land (ISWEL). Within this project, researchers from IIASA's programmes on Water, Energy and Transitions to New Technologies have collaborated in the development of new pathways showing how the world can develop water and energy infrastructures consistent with the Paris Agreement and the Sustainable Development Goal 6 on water (IIASA, 2019).

The International Renewable Energy Agency (IRENA) has analysed how renewable energy technologies can address trade-offs between water, energy and food, bringing substantial benefits in all three key sectors. IRENA's workstream on the nexus produced an in-depth overview report on renewable energy in the water, energy and food nexus in 2015 (IRENA, 2015), followed by more focused work on solar-pumping for irrigation in 2016 (IRENA, 2016a). Additionally, IRENA has examined the potential for renewables-based desalination to address the need for sustainable water supply in the Gulf Cooperation Council (GCC) (IRENA, 2016b). Also, IRENA has studied the water-energy-nexus issue in short quantitative country analyses on the impact of renewables and efficient cooling technologies on water use in the national power sectors of China (IRENA, 2016c) and India (IRENA, 2018).

The World Resources Institute (WRI) published a report entitled *Water-Energy Nexus: Business Risks and Rewards* in 2016. The report assesses emerging risks and offers ideas for finding solutions at the water-energy nexus. It examines two specific questions: Where are companies facing risks at the nexus of water and energy resource challenges? and What are the opportunities for companies to reduce exposure to these risks and meet customers' needs in tomorrow's markets? (WRI, 2016)

The United Nations Economic Commission for Europe (UNECE) published in 2020 a report entitled *Towards sustainable renewable energy investment and deployment: Trade-offs and opportunities with water resources and the environment.* This "tool-kit" publication proposes a pragmatic approach to support policy-makers in: enhancing cooperation on renewable energy across sectors including water; exploring co-financing and partnership opportunities; maximizing and multiplying the benefits of renewables; and reducing their negative impact on the environment and local communities.

Efforts at the regional level

Integrated water and energy solutions at the regional level are being implemented in all the world regions. Important examples are: the Itaipu Binacional Hydropower Plant of Paraguay and Brazil in Latin America, efforts of sub-regional cooperation in the use of water and energy resources in Central Asia, the desalination efforts in the countries of the West Asia region and the GCC, and the Strategic Energy Technologies (SET) Plan of the European Commission.

In **Latin America,** Itaipu Binacional, a world example of successful regional integration, operates the Itaipu Hydropower Plant which is the largest generator of hydropower in the world. In 2018 the plant generated 90 per cent of the electricity consumed in Paraguay and 15 per cent of the electricity consumed in Brazil. Its sustainable development strategy recognizes that integrated water resource management and territorial development are indispensable components of a comprehensive and consistent approach that supports the sustainable use of natural resources while addressing climate change. Also, its integrated actions and programmes supporting social well-being, economic growth and environmental protection, are contributing to regional prosperity in Paraguay and Brazil (Itaipu, 2019).

In **Central Asia**, some parts of the sub-region are rich in water resources, but poorly endowed with conventional energy from fossil fuels; whilst other parts of the sub-region are rich in energy resources, but suffer from a chronic shortage of water for agriculture and human consumption. The dependence of sustainable development of the Central Asia sub-region on the coordinated development and use of energy and water resources is very well recognized by the policy decision makers in Tajikistan and its central Asian neighbouring countries. The Governments of Central Asia sub-region actively participate in the relevant international and sub-regional consultative mechanisms with a view to coordinate the planning, development, and maintenance of the national and regional water and energy infrastructure and the day-to-day management of the energy and water resources. In June 2018, the Government of Tajikistan hosted the first *High-Level International Conference on the International Decade for Action "Water for Sustainable Development" 2018-2028* in Dushanbe to advance integrated decision making on water and energy at all local, national, regional and international levels.

Water desalination is a crucial process for the countries of the **ESCWA region** which have very limited access to freshwater resources such as Gulf countries, as well as some Arab countries including Libya and Algeria. Therefore, rapid increases in installed desalination capacity have taken place in the last two decades. Though desalination is an energy-intensive process, by powering it with renewable energy, some of its drawbacks can be overcome. In addition, renewable energy desalination has the advantage of reduced GHG emissions. Renewable energy desalination plants are operational in Egypt, Jordan, Morocco, and the United Arab Emirates (UAE), but they are mostly of pilot size and do not amount to full utility scale production. Currently, Al Khafji reverse osmosis membrane desalination plant in Saudi Arabia is the world's first large-scale 15 MW photo-voltaic (PV) solar-powered desalination plant. This plant delivers 60,000 m^3 of desalinated seawater per day, ensuring a regular supply of water to the surrounding province the whole year around. In Dubai, an operational PV solar-powered RO desalination station, at the Mohammed bin Rashid Al Maktoum Solar Park, delivers 50 m^3 per day. In Abu Dhabi, ADWEA is spearheading the trend and constructing the world's largest facility of this type in Taweela, with a generation capacity of 900,000 m3 per day. Oman has put in place reverse osmosis in both the Salalah Integrated Water and Power Plant and the Barka II Power and Desalination Plant. The increase in reverse osmosis can serve as an opportunity for greater integration of renewables, such as solar PV and wind, as they become cost-effective alternatives to fossil-fuel-based electricity generation. (IRENA, 2019)

Another important regional initiative has been undertaken by the **European Commission**. In 2008, the European Commission adopted the Strategic Energy Technologies (SET) Plan with the goal to harmonize Europe's energy technology policies. The Strategic Energy Technologies Information System (SETIS) was established as a platform for information exchange in a total of 10 SET areas, including renewables, smart solutions for consumers, resilience and secure energy systems, energy efficiency in buildings, energy efficiency in industry, batteries and e-mobility, renewable fuels and bioenergy, carbon capture, utilisation and storage, nuclear safety, and integrated roadmaps. Although SETIS focuses on energy technologies, it also explored the relevance on the water-energy nexus for EU policies.

Efforts at the national level

Many countries are implementing integrated solutions to water and energy in all the world regions. Selected examples that illustrate some of these efforts are briefly described below. The examples show the wide range of programmes, arrangements, technologies and systems that are being used to address the water-energy-nexus and the many stakeholders that need to work together to achieve progress towards SDG 6 and SDG 7.

In many remote parts of **Australia**, the provision of sustainable water and energy supply poses formidable challenges. One of the recent successful projects was implemented by Hydro Tasmania on Rottnest Island, which is located off the city of Perth in Western Australia. The island previously depended mostly on fossil fuels for its local electric power supply and its desalination system. With the support of the Australian Renewable Energy Agency (ARENA), the Rottnest Island Water and Renewable Energy Nexus (WREN) Project installed integrated additional solar panels and wind turbines into the local island water and energy supply system. Whenever power supply from renewable exceeds local demand, excess power is used for the desalination system. The WREN project has greatly helped to make the Rottnest Island water and electricity supply system more sustainable (Thomson, L., et al, 2017).

In spite of significant progress in recent years, **Bolivia** remains one of the poorest countries in Latin America and the Caribbean. Access to clean drinking water, wastewater disposal, and affordable and reliable electric power is still severely constrained, particularly in the remote rural areas of the country. In addition to seeking to achieve the SDGs, the Government of Bolivia has also announced the Patriotic Agenda 2025, which sets out a more ambitious time frame for sustainable development. Within the framework of a comprehensive water-energy-food nexus project the German International Cooperation Agency (GIZ) is assisting local authorities and village communities in Bolivia with capacity building and with the installation of small-scale fixed and mobile solar-photovoltaic powered pumps for irrigation systems (GIZ, 2018).

The Government of **Cabo Verde** is implementing its Strategic Plan for Sustainable Development, which sets out 39 ambitious development targets for the period 2017-2021. Cabo Verde has greatly advanced on integrated development planning related to energy and water. The country has already made very significant progress to supply its 10 islands and its 500,000 inhabitants with sustainable energy from renewable sources, including wind and solar. Independent power producers, local utilities, and public-private partnerships contribute to a balanced power supply, and to the desalination of water. The Government is also pursuing plans to harness geothermal energy on Fogo Island. Funding has reportedly also been secured to initiate a commercial ocean wave energy project (IRENA, 2014, Government of Cabo Verde, 2017).

Chile's capital city of Santiago and its metropolitan region is facing great challenges in its water management which likely will be further exacerbated by climate change in the future. Energy consumption and urban air pollution also pose growing problems. In response, many urban property developers in Santiago de Chile have already adopted various measures and technologies that make their condominium units not only more comfortable but also more energy efficient. Many property developers use new and improved insulation and ventilation, solar thermal and photovoltaic panels, as well as aerothermal heat pumps, together with smart automation and other water and energy saving measures to reduce energy cost and to help their buyers and tenants to realize energy and water savings (Natural Resources Defence Council, and Adapt Chile, 2019).

In order to better assess the water-energy nexus challenge in **China**, the World Bank's Thirsty Energy Initiative engaged the China Institute for Water Resources (IWHR), the Ministry of Water Resources, and the Tsinghua University (TU) to establish a multi-regional, water-smart energy system planning model, also known as the TIMES-ChinaW model. The Government of China is increasingly aware of the complex interdependencies between water and energy. China's rapid economic development has been accompanied by a similar rapid increase in energy supply and demand, which is dominated by coal, resulting in significant air pollution and carbon dioxide emissions. The coal energy supply chain is water intensive. The water-energy nexus challenge is further complicated by the fact that the majority of the planned new energy projects are located in four Northern provinces of China which have the country significant energy resources but are also among the most water-stressed areas. The modelling of alternative scenarios enabled decision makers in China to optimise investments and policies with a view to ensure sustainable energy supply at reduced levels of water withdrawal and consumption, whilst also remaining within projected trajectories of limited CO_2 emissions (World Bank, 2018b).

Ethiopia is one of the first developing countries which has established integrated institutional arrangements for the coordinated management of water and energy. In Ethiopia, the Ministry of Water, Irrigation and Electricity is in charge of all the activities, planning and infrastructures related to water and electricity, as well as sanitation, allowing for an effective approach to the water-energy nexus.

In **Guatemala**, the Guatemalan Sugar Industry is a long-time committed agroindustry with sustainable environmental and social practices. Not only has it improved its hydric resource management practices, having reduced by 70% the water used in the mills in the last 5 years, it has also invested more than any other industry in the country in Research and Development, leading to innovative practices and solutions, on field and in the mill, that are of the utmost importance to achieve the sustainability of the sector. R&D has allowed the Guatemalan Sugar Industry to evolve and innovate, which is why it not only produces sugar, but also renewable energy and alcohol (ethanol). Another exemplary contribution of the Guatemalan Sugar Industry to the country was the creation of the Institute for Climate Change Research (ICC), now an autonomous organization, as it has become a leader on research and project development to mitigate and adapt to climate change in communities, productive processes and the region’s infrastructure. All based on science and technical knowledge.

In many regions of **India**, the agricultural sector relies on old and inefficient pumps for irrigation. Most farmers cannot afford modern pumps. Inefficient pumps consume much energy and require frequent expensive repairs. During recent years, Energy Efficiency Services Ltd, a public sector company of the Government of India, implemented a comprehensive agricultural demand side management programme. The programme offers farmers to replace old pumps with modern energy efficient ones, which can save energy, and be operated by remote control thus only using water when really needed. Under the programme, farmers would pay for the new pumps in instalments which are the same or lower than their electricity bill savings. The programme provided win-win-win solutions, saving energy and water, whilst also reducing GHG emissions from the agricultural sector (Energy Efficiency Services Ltd, India, 2019). An analysis by IRENA and WRI indicates that using renewables and improved cooling technologies by 2030, the water withdrawal intensity of the electricity generation (excluding hydropower) could be reduced by up to 84%, consumption intensity by up to 25%, and CO2 intensity by up to 43% in comparison to the 2014 baseline (IRENA, 2018).

Over the past 50 years, **Japan** has experienced both increasingly severe local floods, as well as droughts, whilst the average annual precipitation has shown signs of a gradual decrease over time. Enhancing the resilience of municipal water supply and sanitation systems has been an important priority over many years. Some of the country's water supply and sanitation systems are already aging. Seismic activity and earthquakes add additional challenges. In Japan, municipal water utilities are implementing continuous programmes of leak detection and water supply and sanitation piping maintenance and repairs. These programmes have greatly helped to minimize leakage and the associated water (and energy) losses. International sharing of technologies on resilient water supply and sanitation is one of the important areas of Japan's international development cooperation programmes.

Access to clean and affordable drinking water is a great challenge particularly in rural areas of developing countries. In La Mancalona, a small rural village with 450 inhabitants on the Yucatan peninsula in **Mexico**, researchers of the Massachusetts Institute of Technology (MIT), with financial support of the W.K. Kellogg Foundation, have helped to set up a 1,000 liters per day prototype solar photovoltaic-powered reverse osmosis (PVRO) water purification station. The system uses solar panels to charge batteries, which then power pumps that push brackish well water and collected rainwater through filtration membranes. The batteries also supply the ultraviolet sterilization bulbs with electricity. Villagers have been trained to operate the PVRO system. The water purification station has created a viable business opportunity for the village (MIT News, 2015).

Morocco has merged the two public utilities in charge of water (National Office for Potable Water) and electricity (National Electricity Office) by creating an integrated utility (National Agency for Electricity and Potable Water). A national programme for promoting solar pumping in water-saving projects for irrigation has been developed. It has a budget of about US$ 40 million and foresees the development of 3,000 PV pumping systems with a total peak installed capacity of 15 MW. The objective is to improve agricultural yield and productivity, while saving on water and energy.

In order to ensure coordinated investment in infrastructure and a sustainable production, distribution, and consumption of both water and energy, the Government of **Norway** established the Norwegian Water Resources and Energy Directorate (NVE) in 1921. Today, NVE is a Directorate under the Ministry of Petroleum and Energy and is responsible for the management of the country's water and energy resources. NVE aims to ensure an integrated and environmentally sound management of the country's water system, promote efficient energy markets and cost-effective energy systems, and contribute to efficient use of energy. NVE engages in public consultations wherever needed, supports research and development, including on climate change, and implements its own international development assistance programme on water and energy (NVE, 2019).

South Africa is one of the first developing countries in Africa that has conducted a comprehensive national water and energy modelling study. The study was carried out by the Energy Research Center of the University of Cape Town (UCT) as a part of the World Bank's Thirsty Energy Initiative (World Bank, 2017). The research incorporated water supply and infrastructure costs into the energy model SATIM to better reflect the interdependence of water and energy. The modelling effort has demonstrated the multiple benefits of rational and integrated long-term planning of water and energy infrastructure investments. As shown by the model, some additional investments in the energy sector can realize significant saving and benefits in the water sector.

In **Tajikistan,** decision making on energy and water falls under the authority of the Ministry of Energy and Water Resources of the Republic of Tajikistan. Tajikistan relies primarily on hydropower for its electricity generation. Once completed, the Rogun Hydropower plant will be one of the biggest hydropower plants in Central Asia. Its first unit was launched in 2018 and the second one was commissioned in September 2019. The Rogun Plant will include six hydraulic units with a total capacity of 3,600 MW and it is designed as a multi-purpose dam for generating electricity, regulating water, and reducing the risk of floods and droughts.

The **United States** Department of Energy is leading a national effort on the Water-Energy Nexus and in 2014 published a comprehensive report on this issue (USDOE, 2014). The effort recognizes the challenges and opportunities around the water-energy nexus and promotes technical cooperation on this subject among relevant stakeholders. One of the main projects is "The Water Security Grand Challenge" that provides funding prizes for innovative technological systems for desalination, small modular energy-water, wastewater to energy, and low water impact thermoelectric plants.

5. Conceptualizing the Global Knowledge Platform

The relevant review performed for this Scoping Paper serves as the basis for conceptualizing the Global Knowledge Platform and for proposing its possible scope, structure and priority content. The online Knowledge Platform will be used to establish a comprehensive mapping of, and serve as a gateway for, information on existing global efforts, national policies, regulatory considerations, institutional arrangements, data, analytical tools and innovative technological systems related to integrated water and energy solutions. It will build on relevant existing work and mechanisms addressing water and energy. The Knowledge Platform will also facilitate access to information, knowledge and experience, as well as lessons learned on other key means of implementation including financing, technology transfer and capacity building. Aspects of the platform content will be addressed taking into consideration multiple implications resulting from the COVID-19 crisis and future similar world health crises.

The **scope** of the Global Knowledge Platform on Sustainable Water and Energy Solutions could include eight main areas: (1) coordinated global efforts and international cooperation; (2) national policies, regulatory considerations and institutional arrangements; (3) asymmetries; (4) data issues; (5) modelling and analytical tools; (6) gaps; (7) means of implementation (financing, capacity development, technology transfer); and (8) most promising technology areas and innovative systems. The Knowledge Platform could be **structured** following the same categories allowing for a very wide range of areas and subjects for users to select in their searches. The **priority content** of the Knowledge Platform could be about the emerging potential core of integrated innovative systems and technologies supporting sustainable water and energy solutions that offer the best opportunities to realize synergies and efficiencies and that could more effectively support the global goals on sustainable development and climate change also addressing implications related to world health crises such as pandemics.

5.1 Coordinated global effort and international cooperation

A coordinated and integrated approach to water and energy should transcend national borders and could help to diminish potential conflicts arising from the sharing of these natural resources and from climate change. The integrated approach will also help to identify synergies and to avoid negative trade-offs. The Knowledge platform could include a space dedicated to information and lessons learned related to global and regional coordinated efforts on water and energy resources.

This coordinated approach is essential in the pursuit of climate change objectives given the fact that energy and water are key factors in mitigation measures and adaptation procedures. Also the usage and supply of water and energy and their interdependence could be affected by climate change. With global energy-related CO_2 emissions reaching a historical high of 33.1 Gt in 2018, transforming the energy sector is key for mitigating climate change (UN, 2019). Precipitation and temperature patterns are changing all over the world, implying a need to focus attention on adaptation plans. As the impacts from climate change become more evident all over the world, policy makers need to realize the importance of following a coordinated and integrated approach to water and energy that is resilient to climate change impacts. Coordinated efforts on water and energy and integrated water-energy systems will be critical especially for nations expected to experience rapid economic and population growths, nations with large segments of the population without modern energy and water services, nations with limited water and energy resources, and nations highly affected by climate change. Coordinated approaches are also critical to confront the COVID-19 crisis and for a better recovery with contingency programmes that will strengthen the support for health services.

Many developing countries, notably least developed countries, would also greatly benefit from greater international technical and financial support for implementing decentralized water and energy solutions that address the most urgent needs of the urban and rural poor. Without access to water and energy, basic hygienic and sanitary services cannot be provided making the poorest communities of the world without these services fully vulnerable to the COVID-19. Stimulus packages for a better recovery need to consider integrated water and energy innovative solutions that could provide a transformative path resulting in the saving of many lives and on ensuring that no one is left behind.

Coordination of the development of larger-scale water and energy projects is also of particular importance at the regional level. Larger-scale energy projects may be planned to also serve customers in neighbouring countries. Regional interconnections of power grids can help to balance structural differences or temporary fluctuations in national and local power generation and demand and supply and enable participants to use the available energy resources in the most sustainable and climate friendly manner. Electric power pools are operational in practically all developing (sub)regions of Africa, Asia, and Latin America.

Regional and cross-border cooperation is also particularly essential to enable a coordinated management and use of the waters of transboundary river basins. On all continents, concerned governments have formed regional inter-governmental bodies with a view to coordinate river basin-related development efforts. These inter-governmental bodies are well placed to conduct comprehensive development studies and establish forward looking multi-sectoral models, including on the water-energy nexus, to facilitate collaborative planning and decision making processes and manage potentially competing uses of available water resources.[1] For instance, the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (for which the secretariat is provided by UNECE)[2] has facilitated sub-regional consultative processes, including comprehensive water-food-energy-ecosystem nexus studies for international river basins (UNECE, 2018). Related to this work, the Parties to the Water Convention have established a Task Force on the Water-Food-Energy-Ecosystem Nexus, which is a global platform that allows countries and basin organizations to share their knowledge and experience of integrated management of natural resources in shared basins, and related policy action. This space of live dialogue and exchange – particularly on transboundary issues, water management and public policy – shows good complementarity with the online Global Knowledge Platform. The Task Force could help operationalizing the discussion on international cooperation on water-energy nexus on the one hand, and broadening stakeholder outreach on the other.

[1] For a more detailed list of transboundary water management organizations, please see: https://www.internationalwaterlaw.org/institutions/transboundary_wmos.html

[2] For more details on the Task Force see: https://www.unece.org/env/water/task_force_nexus.html

International cooperation is essential to ensure support and progress in the development of coordinated global efforts on sustainable water and energy solutions and to create awareness and disseminate knowledge on the advantages of such integrated approach. Currently, international cooperation is necessary to effectively implement an integrated and efficient approach to water and energy that will support a resilient recovery from COVID-19. More coordinated multi-stakeholder and multilateral efforts are needed to accelerate progress towards practical integrated water and energy solutions. The UN can play a leading role in facilitating a world transformational response by engaging all the stakeholders and continue fostering partnerships such as the Sustainable Water and Energy Solutions Network.

The Global Knowledge Platform on Sustainable Water and Energy Solutions could support this international cooperation by providing an international mechanism for the exchange of knowledge, ideas, data, statistics, forecasts, and lessons learned. The space in the Platform dedicated to coordinated global efforts will allow users to follow progress towards this global objective.

5.2 National and Local Policies, Regulatory Considerations and Institutional Arrangements

Coherent national policies encouraging integrated solutions to water and energy need to be developed and implemented in a timely manner, consistent with sustainable development and climate change objectives. Many nations still do not have these effective relevant policies.

A possible positive consequence resulting from the COVID-19 crisis is that the world may end up better prepared for future pandemics, and nations may be compelled to improve their regulatory architecture for the long haul allowing integrated approaches to water and energy. Reducing barriers to the flow of capital and labour is a way to improve the performance of energy and water investments and operations under emergency and routine conditions. For example, more efficient capital-labour substitutions would enable nations to bolster systems controls automation that improve operations optimization and reduce the risk of human capital shocks on continued operations for critical energy and water systems.

For nations that have full access to water and energy the problem is reliability and the robustness of the related infrastructure and systems. The primary objective for these countries is to maintain operations at all times for critical water and energy services but another major source of vulnerability is affordability. The systemic inequalities that exist in many countries, including developed countries, have resulted in the fact that the poorest segments of the populations are the ones most affected by COVID-19. (UNDESA, 2020) The poorest are the ones with the smallest households, who live in crowded neighbourhoods and the ones who need to use public transportation and need to work to keep their jobs even when social distancing policies are enforced. One of the main consequences, once the economic crisis started to take place, is the inability of the poorest to pay for the energy and water services. Special policies for a time of crisis that could be based on flexible tariffs, perhaps according to different income levels, represent key tools for decision makers during these types of crises.

In rural isolated communities and urban squatter communities the problem is the lack of running water and electricity connection. The problem in these places is indeed the lack of access to these critical services which make life conditions unbearable at all times but especially during the COVID-19 pandemic. Sustainable water and energy solutions are a must for these communities and an urgent goal that needs to be satisfied to eradicate poverty and to save lives.

Policymakers need to stay focused on addressing the crisis at hand. Crises induce motivation for reform, and thoroughly deliberated regulatory reforms remain worth pursuing to better position the water and energy sectors for a cleaner, more prosperous, and more secure future that could save lives.

Institutional and legal frameworks for the integrated management of water and energy need to be developed and implemented at national and regional levels. Many nations still depend on independent institutions to manage water and energy without taking into consideration the high interdependence of these two factors and current and future impacts from climate change. Only some nations already have frameworks in place to manage these factors in an integrated fashion.

Relevant ministries in nations all over the world need to formulate coherent water and energy policies and programmes, taking into consideration national priority needs, the availability of resources, the interests and competencies of local actors, options for mobilization of financing, established legal and regulatory requirements, as well as environmental and climate concerns. Several developing countries have seen an advantage in combining the concerned ministerial portfolios of water and energy. Among others, the following countries have established Ministries of Water and Energy: Afghanistan, Angola, Barbados, Cameroon, Ethiopia, Lebanon, Malta, Morocco, Nepal, Pakistan, Qatar, Rwanda, Somalia, and South Sudan. In other countries, ministerial portfolios on water, irrigation and energy are linked with other issues, including the development of other infrastructure, or other natural resources or industries, and environmental protection. Several countries have established departments specifically dedicated to enhancing the development and use of renewable sources of energy. Regardless of the particular national institutional arrangements, the main concern remains the inter-sectoral and inter-disciplinary coordination in the planning processes. Extensive consultations with concerned stakeholders also need to be institutionalized and implemented. Another important dimension is the actual allocation of resources for integrated water and energy development by the respective central planning authorities and finance ministries.

At local levels, initiation, planning and coordination of investments in water and sanitation typically fall within the mandate of municipalities and local authorities and the respective public enterprises. Investments in decentralized power generation systems may also be coordinated in consultation with local authorities. Planning capacities and location of local water, sanitation and energy infrastructure offer essential opportunities for synergies and efficiency gains (IEA, Excerpt 2016). Local integrated urban and rural development plans are best developed in direct consultation with the communities concerned. National authorities may provide the enabling framework and support local planning and decision making with expertise and capacity building.

The Knowledge Platform could have a space fully dedicated to information and data on national policies, regulatory considerations and institutional arrangements being implemented worldwide. The information in this space could be very valuable for policy makers in the definition and implementation of their own national policies, regulations and institutional arrangements.

Policy makers and experts from public and private sectors need to be aware of and to understand that there are major asymmetries between energy and water in relation to economics, commercial issues, politics, governance, and data availability.

In most countries, energy is a major economic domain and a factor perceived by many as very important with great value and that represents a significant cost to people in the household, industrial, manufacturing, services, and agricultural sectors of the economy. As such, decision makers in both public and private organizations commit considerable resources of all kinds to attend the planning, availability and reliability of energy systems. It is also a factor that normally can be quantified and measured through time and space facilitating its control and accountability for commercial purposes.

Water, although an indispensable factor for life and for economic and social development, is in many places regarded as a public health and welfare issue. In fact, access to clean water and proper sanitation is considered a human right in which water resources are taking as a public good. Also, water resources are subject to great variabilities in time and space which are already intensifying due to climate change impacts. The worldwide variability in the water cycle makes it more difficult to measure and to assess water issues and to build comprehensive and disaggregated sets of data, statistics and indicators. In many cases, the management of water resources is mainly a responsibility of state, municipality and local organizations.

In general, prices of water and energy typically do not reflect the true scarcity, societal costs or economic value. Subsidies and political decisions could greatly affect the prices of energy and water altering the true economic link between water and energy. In a lot of countries, the price of water seldom reflects even its basic cost associated with storage, treatment and distribution and in many cases the price is indeed lower than the basic cost of supply.

Therefore, market forces tend to play a greater role in energy sector development than in issues related to water such as water resources management and water-related services. Consequently, in the past energy has attracted considerably more political attention than water in most countries reflecting this economic, commercial and social disparity. Only recently there is more global awareness of the importance of water given the eminent crisis happening in many countries due to lack of water resources and the already negative impacts on water resulting from climate change.

Policy makers need to be aware of these asymmetries to be able to develop effective and sustainable integrated water and energy solutions. The different political economies of water and energy should be recognized, as these differences affect the scope, speed and direction of change in each factor. Partly because of these issues, there is a considerable difference in the pace of change in the water and energy sectors. The incentives to increase efficiency facing the two factors are asymmetrical. In many cases, energy users have little incentive to conserve water due to its low cost, but water users normally do pay for energy, even though prices may be subsidized (UNESCO, 2014 and 2019).

The discussion about whether energy and water should be public goods has intensified with the COVID-19 crisis. During health world crises like pandemics, the need for reliable and appropriate water and energy services becomes more evident. In countries where there is full access to these services but with communities financially vulnerable, the problem is affordability for these basic utilities. The problem becomes severe when people start to lose their jobs and countries' economies enter recession. In these situations, many families simply cannot afford paying for these basic services which will increase the risk for more people to get infected with the virus. Therefore, lack of affordability increases vulnerability. In countries or communities with low or no access to these services, there is the potentially catastrophic situation of having an uncontrolled spread of viruses. Policy makers need to assess these possible scenarios to determine the best way to ensure access, availability, reliability and affordability of these services.

The Knowledge Platform could be an effective mechanism in the dissemination of information related to asymmetries between water and energy and on guidance to overcome these asymmetries. Stakeholders including policy makers and experts interested in the implementation of integrated water and energy solutions will benefit from space dedicated to information and discussion related to these important asymmetries.

5.4 Data issues

There are many issues related to data that need to be taken into consideration in the development of sustainable water and energy solutions. As described in the asymmetries section, considerable and reliable data including historical trends, disaggregated data and projections on production and consumption are available from the energy sector. In general, the same level of data is not available from the water sector representing a challenge for decision makers while assessing synergies and trade-offs that may result from the implementation of integrated water and energy projects. The lack of relevant water data is particularly important in relation to water withdrawals and consumption by energy systems and with respect to the energy intensity of water treatment and distribution systems.

Lack of shared, transparent data and information across sectors creates difficulty in analysis and planning as well as in infrastructure design for water and energy. In many countries there are few mechanisms and incentives across agencies for data sharing, which makes joint and integrated planning even more challenging.

Another challenge is that many organizations and businesses are obliged to treat their data as confidential. Hence, some of the available data may not be accessible, even for legitimate research purposes.

A lot of the data needed to assess and develop sustainable energy and water solutions is related to social, economic and environmental projections into the future. Although there are many modelling and simulation techniques that try to develop integrated projections and alternative future scenarios, in many cases the basic information, data and indicators to run these models are not available, especially in developing countries.

Developed countries have a marked advantage over developing countries because, in general, they have robust institutions that collect, interpret and manage aggregated and disaggregated data that are indispensable for the effective use of modelling tools and for assessing future scenarios and potential integrated water and energy solutions.

The Global Knowledge Platform on Sustainable Water and Energy Solutions could play an important role not only for collecting relevant statistics, data and information about effective integrated approaches to water and energy but for promoting the development of balanced sets of data, statistics and indicators relevant to future sustainable water and energy solutions.

5.5. Modelling and analytical tools

Given the complexity in the management and optimal use of natural resources, a growing number of national economic planning authorities and several international organizations are engaged in global and regional water-energy nexus modelling efforts. Many comprehensive, integrated and long-term modelling extend to cover, in addition to water and energy, land and/or food security. These efforts are very valuable at the national and regional levels, but they depend on the availability of disaggregated data that sometimes are not readily available particularly in developing countries.

Some planners for public investment in water and energy infrastructure build their projects on projections, including present and future availability of (cooling) water for power plants, or electricity supply for powering pumps and aerators in water treatment. However, over time, a number of independently planned projects have encountered some unexpected difficulties. In South Africa, for instance, some coal-fired power plants are forced to retrofit their facilities and to switch from once-though cooling to more expensive forms of dry-cooling, due to previously unexpected shortages of cooling water supply. With timely water-energy nexus modelling and integrated planning some costs could perhaps have been avoided (World Bank, 2017).

Today, a growing number of national economic planning authorities also embark on some more comprehensive modelling efforts as a part of their intermediate or longer-term public investment planning. Modelling techniques and software programmes are accessible, and the necessary skills are also available at public or private local or international universities and research institutes particularly in developed countries. However, in many cases, the application of modelling tools is still constrained by a lack of some of the necessary data. Whereas energy related technical and market data are comparatively easily available, water related data is often more difficult to find. In some cases, data for some essential indicators may not be collected regularly, or may not be collected at all, especially in developing countries.

Several international organizations, including the International Energy Agency (IEA), the World Bank Group, and the International Institute for Applied System Analysis (IIASA) are engaged in global and regional water-energy-nexus modelling efforts (IEA, 2016 a, IEA, 2016 b; IIASA, 2018). Some 63 counties have participated and made use of the IEA-ETSAO Energy Technology Systems Analysis Programme. The IEA modelling tools can be amended to include water related modelling. The *Thirsty Energy Initiative* and the *Water, Energy, Food Security Resource Platform* of the World Bank also make information and resources on integrated modelling on water and energy planning and investment available (Rodriguez, et.al, 2013; World Bank, 2018). Various modelling studies are available on the *Nexus Resources Platform on Water, Energy and Food Security Resources*, hosted by the German Agency for International Cooperation (GIZ).[3]

Comprehensive, integrated and long-term modelling is particularly important in the context of river-basin-based water and energy planning, especially when the

[3] www.water-energy-food.org

activities concern international water-courses. The International Institute for Applied Systems Analysis (IIASA) has undertaken water-energy-nexus studies for the trans-boundary Zambezi River Basin in Africa, and for Indus River Basin in South Asia (IIASA, 2018). As part of the nexus assessments under the Water Convention (see section 5.1), a number of such integrated models – including, among others, for the Sava and Drina River Basins in Europe and the Syr Darya River Basin in Central Asia - were developed by KTH Royal Institute of Technology using open source modelling tools (UNECE, 2018) (de Strasser, et al. 2016) (Almulla et al, 2018) (Ramos et al, 2020).[4]

On all continents, concerned Governments have formed regional inter-governmental bodies with a view to coordinate river basin development efforts (e.g. Mekong River Commission, founded 1995). These inter-governmental bodies are well placed to conduct comprehensive development studies and establish forward looking multi-sectoral models, including on the water-energy nexus, to facilitate collaborative planning and decision-making processes.

The Knowledge Platform may include a section fully dedicated to the integrated planning and modelling tools supporting rational and participatory decision making on water and energy projects. Several members of the Sustainable Water and Energy Solutions Network have institutional experience and competence in establishing and analysing water-energy nexus models and may consider reporting on their tools and sharing their experiences via the Global Knowledge Platform.

5.6. Gaps

The review points toward areas where there are important gaps that need to be addressed in order to develop effective, sustainable and integrated water and energy solutions. One of the main gaps is related to the asymmetry on the availability of data on water and energy described in previous sections. The gap in data availability is critical in many developing countries and represents a limitation for the development of future scenarios and the use of integrated modelling systems in these countries.

An important gap is related to the lack of methodological tools that allow measuring the economic, social and environmental value resulting from services provided by combined water-energy systems. Multipurpose hydropower plants represents an example in which benefits in the three dimensions of sustainable development need to be properly measured in addition to measuring the cost and benefits of generating electricity. Additionally, innovative modelling mechanisms are necessary to assess the opportunity and risks related to the use of water as energy storage while considering all other potential water uses.

Another challenging area identified in this review is related to the design and development of integrated systems for the poor. More effective efforts are necessary worldwide for the development of sustainable water and energy solutions specifically tailored to cover the needs of the poorest segments of the population which usually are the ones without access to basic energy, water and sanitation services. Even though many projects exist that seek to advance sustainable rural socio-economic development, many challenges persist. Challenges

[4] More information available at: https://www.energy.kth.se/2.89906/about-the-division-of-energy-systems-1.937036

are related to funding, capacity development and the persistent focus on one of the two factors instead of both. Also, the success and sustainability of the projects are often affected by the lack of long-term capacity development programmes that need to be implemented at the community level.

Currently, one of the main gaps or areas that need attention is the assessment of the potential impacts of the COVID-19 world crisis in the critical services of water and energy. There is little information about the consequences that an extended world health crisis could have on these services. Possible negative impacts are related to the potential unavailability of critical workforce necessary to run and maintain these utilities which need to operate 24 hours a day. The crisis points towards the need to enhance protections and benefits for energy and water industry workers who should be classified as “essential” staff to critical infrastructure and services. The proximity of working conditions in certain work areas such as control rooms could put entire facility workers at risk of uniform COVID-19 exposure. Refuelling and maintenance activities in facilities like power plants may need to be rescheduled or delayed to ensure short term availability of the services while increasing the risk of shutdown in the mid or long term. (Hartman, 2020) Additionally, the availability of inputs such as chemicals, fuels and materials could also compromise the reliability of these services. The availability of mineral supplies such as cobalt, nickel, cooper and rare earths supporting clean energy technologies for the future is also an issue that needs further review. (IEA, 2020b) More importantly, the strong interdependence between water and energy entails that the disruption in the supply of one of these critical inputs will eventually force the disruption of the other supply. These are issues of paramount importance for policymakers in relation to the generation of electricity and the treatment, distribution and management of water.

The need to address the major challenges resulting from gaps in methodological tools and in technologies and systems development could be specifically treated in a dedicated section of the Global Knowledge Platform. The specific space will collect data on identified challenges and provide information on progress in the development of innovative models to eliminate important gaps not only in monitoring comprehensive benefits of multi systems but on developing water-energy integrated systems for all.

5.7. Important Means of Implementation: Financing, Capacity Development and Technology Transfer

The policy makers, technical experts, practitioners, academia and other stakeholders involved in integrated efforts on water and energy have recognized the many challenges that exist and that need to be overcome in order to accelerate a transformational path to sustainable water and energy solutions. Among these challenges there are important Means of Implementation which greatly affect developing countries and particularly the Least Developed Countries. They include financing requirements, capacity development and technology transfer. The Global Knowledge Platform could become an important mechanism supporting these means of implementation.

A dedicated section can be included for information on innovative financial models for integrated water and energy approaches. The Platform could serve as a place where stakeholders searching for financing opportunities could find information about potential financing arrangements and financial institutions interested in advancing integrated energy and water solutions. By providing this service and information, the Global Platform will be supporting one of the main objectives of the Network of helping to mobilise and scale up multi-stakeholder financing actions aimed at stimulating integrated water-energy responses.

The current global crisis that has unfolded as a result of COVID-19 presents an opportunity to overcome inertia and unlock private capital to the long-term benefit of the economy and the environment. Harnessing worldwide enthusiasm for more resilient water and energy systems could allow the development of transformative pathways to reduce inefficiencies and secure robust energy and water infrastructures. Although these systems may require significant up-front investment, in the long run and anticipating the possibility of other future world health crises these investments will clearly translate into savings not only of financial resources but also of human lives.

Another space in the Knowledge Platform could be assigned to capacity development activities. It could include information about seminars, symposiums, training tools on this subject, as well as information about institutions offering these capacity building opportunities including academia and international organizations. This particular section of the Global Platform will support the Network objective of strengthen capacity building with a focus on the planning, designing, implementing and monitoring of policies, regulations, business models and investment to effectively manage the water-energy interlinkages and enhance integrated decision making. In order to advance capacity building and information sharing, and to attract the attention of more policy and decision makers, the Network may also consider to periodically organize its own international conferences and workshops, always avoiding duplication of efforts by other organizations. The Platform could then serve to disseminate information, not only on logistics, but also on outcomes, reports, proceedings, and recommendations.

Technology transfer is essential for many developing countries. More technologically driven solutions that follow an integrated approach are becoming available in different countries as policy makers and technical experts come to terms with limited water and energy resources while demand for these resources keep increasing and their availability may be compromised by climate change impacts. Nevertheless, COVID-19 has made evident the urgency in the development and implementation of practical, integrated and effective innovative technological systems that would support the reliability of these critical services during world health crises. The Network is committed to facilitate the exchange of technical information among relevant stakeholders and the Global Platform could assist with a dedicated space for dialogue and for enhancing knowledge sharing on science, technology and innovation. With this dedicated section, the Knowledge Platform could also become an effective global technology facilitation mechanism on sustainable water and energy solutions.

5.8. Most promising technological areas and innovative systems

The review performed allowed the identification of a number of technologies and technological systems that represent effective solutions in which synergies could be realized and that could also help to diminish negative trade-offs resulting from implementing independent solutions to energy and water challenges.

In relation to energy systems, the most promising technological systems include those related to hydropower plants, energy-storage, cooling systems in thermal plants, geothermal, ocean energy, bioenergy and hydrogen.

With regard to water systems, the most promising areas include enhancing energy efficiency of water supply and distribution systems, wastewater recycling and wastewater efficiency improvements, renewable energy generation from wastewater, and desalination using renewable energy.

In relation to areas without access to energy grids and water distribution systems, the most promising systems are those decentralized distributed systems and micro-grids designed to meet basic water and energy needs of the urban and rural poor in developing countries in an integrated manner.

The Priority Content of the Global Knowledge Platform could include, as starting point, these selected technologies and technological systems that represent some of the best options for integrated sustainable water and energy solutions. The Knowledge Platform could have dedicated sections or spaces to each of these technological systems with cross sectoral information in relevant areas such as data issues, modelling, policies, regulations, institutional arrangements, financing, capacity development, technology transfer, etc.

6. Priority Content: Technologies providing sustainable water and energy solutions

The Sustainable Water and Energy Solutions Network set itself the ambitious task to identify and advance the most important and most promising integrated and effective solutions to the sustainable development of water and energy. Against this background, the review performed for this Scoping Paper has identified initial areas where technologies and innovative systems are available to advance sustainable water and energy solutions. These areas could represent the initial priority content of the Global Knowledge Platform.

6.1 Technological systems using water for energy

Reliable and efficient energy services are critical during a time of a crisis like the one the world is experiencing in 2020 due to the Covid-19. As the lives of people all over the world are upended in some way by the COVID-19 pandemic, many developed countries have relied on relatively robust energy systems. In these countries, energy companies are working to keep the lights on and natural-gas providers continue to supply their product to homes through pipeline systems. However, many developing countries do not count with reliable energy systems that could face a pandemic lasing months or years. Additionally, there are many communities in the world that lack access to energy services, particularly Least Developed Countries and Land-Locked Developing Countries.

Integrated energy and water systems provide an opportunity to realize synergies that can help to address the need for the basic services of energy, water and sanitation in tandem. Understanding the benefits of integrated approaches to water and energy are particularly important for developing countries to ensure that health and sanitation facilities can count on the continuous availability of the critical inputs of water and energy. International cooperation is necessary as well as strong support from the private sector which is indispensable to complement public efforts.

The current situation presents an opportunity to increase the reliance on renewable energy technologies that use less water as compared to technologies based on fossil fuels. The goal is to build more resilient and reliable water and energy services for the world to be better prepared for future pandemics.

Hydropower generation from surface water resources

Hydropower from large dams and reservoirs accounts for about 16 per cent of today's global electricity generation, and about 70 per cent of all electricity produced from renewable sources. Around the world, more than 70 large-scale hydropower dams (with more than 2,000 MW capacity each) are currently in operation, and nearly 20 more large dams are being planned or under construction.

Over the years, the International Hydropower Association, which is also a member of the Global Water and Energy Solutions Network, has established *Hydropower Sustainability Guidelines on Good International Industry Practice* (IHA, 2018 a), the *Hydropower Sustainability Assessment Protocol (HSAP)* (IHA, 2018 b) and the *Hydropower Sustainability Environmental, Social and Governance Gap Analysis Tool* (IHA, 2019 c). These tools are helping the industry, including project planners, operators, assessors, regulators, and investors, to comply in full with all sustainability principles, concepts and standards. These hydropower sustainability tools are governed by the Hydropower Sustainability Assessment Council which is a multi-stakeholder organization.

Large hydropower stations can sustainably produce electricity at low cost. Hydropower stations can have a very long service life and, once constructed, hydropower generation produces relatively low direct waste or greenhouse gas emissions. Water temporarily stored in the reservoirs is returned to the river usually without major changes, and only some water is consumed through evaporation. Apart from generation, storage hydropower also provides flexibility and ancillary services, water management services, and enables higher penetration of variable renewable energy.

Many hydropower stations have already been operating for many years, and some are in need of extensive maintenance, repairs, or turbine refurbishments. Modernization, automation, and capacity expansion of existing hydropower facilities may require significant investment but offer great potentials for increasing electric power output in a more efficient manner in relation to water use. The Intergovernmental Panel on Climate Change in its report on hydropower in 2011 pointed out the needs and the economic opportunities of renovation, modernization and upgrading of hydropower facilities (IPCC, 2011). The World Bank has also addressed these issues in a recently launched report on operating and maintenance strategies for hydropower (World Bank, 2020).

The majority of the world's large dams were not built for hydropower purposes, but for water management purposes, such as irrigation, flood control, navigation, and urban water supply schemes (World Commission on Dams, 2000). Water management dams release their water reserves, mostly by gravity via canals and pipes to where the water is needed for irrigation, urban water supply, or other purposes. There are large unused potentials for producing electricity from non-conventional small-scale hydropower turbines, as the water flows towards the users. Retrofitting some of these existing dams with turbines may represent a substantial hydropower potential with only limited environmental impacts, because only about 25 per cent of large reservoirs are currently used for hydropower generation (USDOE, 2014). The Knowledge Platform may provide relevant information including data and statistics to planners and decision makers to assess the potentials for retrofits, which would need to be carefully planned on a case-by-case basis and assessing environmental impacts.

Run-of-river hydropower generation

Run-of-river (RoR) hydroelectric plants generate electricity by using parts of natural river water flows and natural elevation differences. Water from the turbines is released on-site and returned unaffected back into the river. Fast flowing rivers with steady seasonal waters offer good options for genuinely sustainable run-of-river power generation.

Whilst there are about 70 large-scale run-of-river hydropower stations around the world with capacities ranging from 100 to 1,500 MW, most commercial RoR power stations are smaller and have capacities between 15 and 75 MW. The production rate of run-of- river projects is typically more stable than those of wind or solar power systems, but production may vary depending on the seasonal volume of water. Run-of-river hydropower generation is an important renewable climate friendly source of energy. However, in some regions production could be constrained in the future if and where regional weather and precipitation patterns change (IPCC, 2011).

The Global Knowledge Platform could include international information not only on the design, construction and operation of RoR power plants, but also on possibilities for capacity expansion, efficiency and sustainability enhancements. Information sharing on smaller run-of-river power stations will be of particular interest to those developing countries which seek to enhance the use of their rivers for affordable, sustainable, and climate-neutral electricity generation.

Pumped-storage hydropower and energy storage from hydropower reservoirs

Hydropower also serves as a major source of energy storage. In such a system, water is pumped from a lower reservoir into an upper reservoir during off-peak hours, while flows are reversed to generate electricity during the daily peak load period or at other times of need. Although some losses can occur during the pumping process, pumped-storage hydropower provides great economic and environmental benefits. Pumped storage is the largest capacity form of grid energy storage presently available worldwide. Integrated systems that use new renewable energy sources such as wind and solar could be used to supplement the process of pumping water from the lower reservoir to the upper reservoir.

With an estimated total global capacity of 140,000 MW, pumped-storage plants play a crucial role in making electric power supply systems more viable and sustainable. Japan has over 27,000 MW, the US has about 23,000 MW, and Europe has about 25,000 MW of operating, but also aging, pump storage facilities. Pumped storage facilities can produce even more electricity with less water in the future if the older existing plants install newer turbines and generators, and if the use of variable speed drive technology is increased. Rehabilitation and modernization of pumped-storage facilities has emerged as a major trend in the past years.

A recent comprehensive policy brief published by the Institute for Integrated Management of Material Fluxes and of Resources of the United Nations University (UNU-FLORES) has highlighted important options for hydropower reservoirs to provide energy storage for balancing and for a better integration of renewables (UNU-FLORES, 2015). Hydropower has an important role to enable the integration of higher share variable renewables in energy systems. A Norwegian team of researchers has also pointed out valuable options of Norwegian hydropower stations to balance fluctuations in power generation of intermittent renewable energy sources in the European power grid (Harby, A., et al, 2015).

The Global Knowledge Platform on Sustainable Water and Energy Solutions could include information relevant to pumped storage facilities, and encourage stakeholders to undertake continued investments in the operational efficiency of the existing facilities, also with a view to ensure optimal use of limited water and energy resources.

Water-based cooling systems in thermoelectric power plants

Global power generation depends for more than 70 per cent of its capacity on thermal power plants using coal, natural gas, or nuclear fuel (IEA, 2016a). The thermal power sector withdraws very significant amounts of water for cooling, mostly from surface water sources. Much of the cooling water is returned to the source after use but often at a higher temperature than at the withdrawal, thus potentially causing thermal pollution with negative impacts on aquatic life. As estimated by the IEA, worldwide power generation including primary energy production accounts for approximately 10 per cent of total global water withdrawals, and some 3 per cent of total water consumption (IEA, 2016a, IEA, 2018b).

The intensity of water use and energy dissipated varies with the respective fuels and the generation and cooling technologies. There are three main types of cooling technologies: “once-through”, “wet-tower” (recirculation system), and air-cooled condensers for “dry cooling”. There are trade-offs associated with each cooling technology in terms of water withdrawals versus consumption, capital costs, and impacts on water supplies. In general, once-through technologies are the most efficient and have the lowest capital cost requirements but have the highest withdrawal rate. Wet-tower technologies withdraw less water but consume more. Dry cooling on the other hand uses very little water but is more expensive and has the lowest efficiency (IEA, 2016 a).

After hydropower, thermoelectric power generation is one of the most important areas of focus in the water-energy nexus because of its dependence on water resource availability for cooling. Cooling needs vary with the fuel type and the power plant combustion technology and its efficiency. Coal-fired power plants typically have higher cooling needs than natural gas combined cycle (NGCC) plants. Nuclear power plants have much higher and special cooling technology needs. There are multiple options for reducing water withdrawal and water consumption of thermoelectric plants. One approach is to reduce the generation of waste heat through more efficient power cycles (e.g. recompression closed-loop Brayton Cycle). Another approach to improve the water efficiency of cooling systems is through modifications and advancements in technology, including more efficient air flow design, improved water recovery systems, changing over to hybrid or dry cooling, and treatment of water from blowdown.

Making existing and future power plants more energy-efficient and less freshwater water consuming will need to be a core concern for policy makers and managers of power systems. The Global Knowledge Platform may serve to publicise and share information on energy and water efficient power plant designs, the related products and processes, and the successful implementation of good practices.

Geothermal energy use for heat and electric power generation

Geothermal energy systems, also known as hydrothermal energy systems, are widely considered an important renewable resource, as the constant flow of heat from the core of the earth ensures an uninterrupted, inexhaustible, and essentially limitless supply of energy. Some applications of geothermal energy use the earth's temperatures near the surface, whilst other systems require drilling deep wells.

More importantly, geothermal power plants can transform natural heat into electricity whilst mitigating carbon emissions. In 2017, the aggregate global geothermal power generation capacity stood at 14 GW, with a total annual production of an estimated 84.8 TWh. Global geothermal power capacity is expected to rise to over 17 GW by 2023, with the biggest capacity additions expected in Indonesia, Kenya, Philippines and Turkey (IEA, 2018a). Geothermal power generation at scale is only economical in or near volcanically or tectonically active regions (IRENA, 2017). Geothermal power plants consume less water per kilowatt-hour of lifetime energy output than other electric power generation technologies. However, lifecycle water consumption varies with the specific type of the geothermal power plant system. Geothermal power plants can provide a stable production output, unaffected by seasonal or climatic variations, resulting in high capacity factors (ranging from 60 to 90 per cent) and making the technology suitable for baseload production (IEA, 2018a). However, each geothermal source is unique in its location, temperature and pool depth, and the choice of suitable designs and geothermal technologies will need to be adapted in each case.

Several international expert networks have been established to facilitate technology and information exchange among geothermal experts around the world. These include the Technical Cooperation Programme (TCP) on Geothermal of the International Energy Agency (IEA), the Global Geothermal Alliance, supported by the International Renewable Energy Agency (IRENA), as well as the International Geothermal Association (IGA). The Global Knowledge Platform on Sustainable Water and Energy Solutions may complement these networks and facilitate their interaction and information exchange, particularly with a view to benefit experts from developing countries.

Ocean Energy Technologies

Ocean energy technologies are commonly categorised based on the resource utilised to generate energy. Ocean energy includes tidal stream, tidal range, wave energy and Ocean Thermal Energy Conversion (OTEC). The theoretical resource potential of ocean energy is more than enough to meet present and projected global electricity demand well into the future. IRENA projects in its Energy Transition scenario aligned with the objectives of the Paris Agreement (REmap case) that ocean energy could exceed 100 GW of installed capacity by 2050. At present, ocean energy technologies are still in developmental stages, with most technologies in the prototype phase and some just reaching commercialisation and cumulative installed capacity only amounting to 529 MW in 2018. Nevertheless, substantial growth in deployment and installed capacity is expected in the coming years.

Tidal stream and wave energy converters are the technologies of greatest medium-term relevance. They are the most advanced ocean energy technologies available, albeit at a pre-commercial stage. Tidal projects can produce variable, but highly predictable, energy flows. Several pilot projects are also under way to generate electricity from ocean waves. Offshore tidal energy systems account for the smallest portion of renewable electricity globally, and the majority of projects remains at the demonstration phase. However, with large, well-distributed resources, offshore tidal has the potential to scale up over the long term (IEA, TCP on Ocean Energy Systems, 2019). A number of pioneering companies is also exploring hybrid renewable energy projects with combined wind and wave technology, as well as ocean-based floating wind or solar farms.

Other ocean energy technologies that harness energy from the differences in temperature and salinity of ocean water such as OTEC may become increasingly relevant over longer time horizon. OTEC's generation is based on the temperature difference between the surface and deeper layers of the ocean. The largest OTEC plant is in Hawaii as a testing facility with an installed power capacity of 210 kW. OTEC plants continue to be of interest, particularly in island applications, as they provide the possibility of using the cold deep water as well as the warm surface water flow for purposes other than energy generation, such as desalination, aquaculture and cooling.

The International Energy Agency supports a Technical Cooperation Programme (TCP) on Ocean Energy Systems (IEA, OES TCP, 2019) with a view to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable way. There are currently 21 contracting parties, including developing country partners from China, Mexico, Nigeria, and South Africa.

IRENA, as a leading global intergovernmental organisation dedicated to energy transformation, is supporting countries in gaining access to the latest knowledge on marine energy, in the context of national strategies to achieve SDG 7 and SDG 14 (oceans), and support capacity building and international cooperation to foster a global blue economy. IRENA provides a common vision on marine energy potential and expected changes in the market, helping to disseminate the best marine energy experiences and providing to policy makers case studies, business cases and facts on the technology.

The Sustainable Water and Energy Solutions Knowledge Platform may also support the dissemination of information on ocean energy projects with a view to encourage further research and development efforts in this potentially important renewable energy area.

Bioenergy

Bioenergy is renewable energy from organic material corresponding to the feedstock categories of agriculture, forestry and waste. Bioenergy can be used for transportation, heating and generation of electricity. Sustainable bioenergy can contribute to climate change objectives helping to reduce the consumption of fossil fuels. It can also contribute to agriculture and rural development and energy security. It is important, however, that bioenergy development be based on sustainable water management practices that take into account other uses of water as well as food security. Integrated approaches to bioenergy include innovative systems and strategies that maximize water use efficiency. Furthermore, a variety of examples exist of bioenergy systems in different world regions that contribute positively to the state of water (GBEP & IEA, 2016).

Hydrogen

Hydrogen is light, storable and energy-dense and has no direct emissions of pollutants or GHGs. Hydrogen production through water electrolysis represents an energy option that has been gaining momentum in the last decade. Hydrogen can be produced from water by utilizing electrolysers that split water into hydrogen and oxygen using electricity. With declining costs for solar PV and wind, renewable electricity could be used to produce hydrogen. Hydrogen has a great potential as a clean source of energy for the transportation, building, industry and power sectors.

6.2 Technological systems using energy for water

Annual water consumption is increasing worldwide. The consumption of water on a per capita basis varies considerably from country to country both in developed and developing regions. For example, in 2016, total annual consumption of water per capita (including for industry and agriculture) ranged between 311 m^3 per person in Germany, and 1,582 m^3 per person in the United States.[5] Of the 2.1 billion people who do not have access to safely managed drinking water today[6], around 1.6 billion must walk to get their water, while almost 600 million drink directly from an unprotected well, spring, or surface water, risking illness from contaminated water.[7]

About 1.3 billion people have no access to basic water service, that is defined as an improved drinking water source that can be collected in 30 minutes or less round trip. More than 2.5 billion people do not have access to proper sanitation. Every day, more than 2,200 children below the age of 5 die as a result of diarrheal diseases.[8] Expansion and improvement of water supply systems is urgent, particularly in developing countries.[9]

Today more than ever sustainable water solutions are needed to support nations in their fights against health crises such as the 2020 pandemic due to Covid-19. For the 3 billion people without basic handwashing facilities at home, practicing social distancing represents a real challenge (WHO, 2019). Innovative water-energy services resulting from integrated approaches in water and energy provide effective ways to expand water access while using clean sources of energy. For regions experiencing water stress and with population at risk due to COVID-19, integrated water and energy approaches can make a difference.

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5 For data on the water sector in several countries please see https://www.statista.com/statistics/263156/water-consumption-in-selected-countries/

6 Safely managed drinking water is defined as use of an improved drinking water source that is located on preminses, available when needed and free from contamination. According to the World Health Organization (WHO) und United Nations Children's Fund (UNICEF), improved water solutions include piped water, boreholes or tubewells, protected dug wells and springs, rainwater and packaged or delivered water.

7 www.washdata.org

8 https://www.cdc.gov/healthywater/global/wash_statistics.html

9 For detailed information and statistics please see: https://ourworldindata.org/water-use-sanitation

Desalination of (sea)water

A large number of countries in Africa, the Middle East and Asia are under serious freshwater stress. Desalination plays an important role to meet freshwater needs in selected locations. Water desalination is highly energy intensive and energy needs are typically met by fossil fuels, mostly natural gas. Energy consumption and greenhouse gas emissions from desalination are widely projected to increase rapidly.

The most prevalent forms of desalination include thermal desalination and reverse osmosis (RO). Thermal desalination uses heat energy to separate distillate from high salinity water. In reverse osmosis, membrane barriers and pumping energy are used to separate salts from high salinity water. Desalination technologies can be used to treat brackish groundwater, surface water, seawater, or even wastewater.

Global desalination capacity has grown from 64 million m^3/day in 2010 to close to 98 million m^3/day in 2015.[10] Countries where desalination is most used include the Kingdom of Saudi Arabia, the United States, the United Arab Emirates (UAE), Australia, the Islamic Republic of Iran, China, Kuwait, and Israel. Reverse osmosis is the predominant type of desalination technology today. As energy needs and energy costs are high, desalination facilities are often located near power plants. The costs of desalination can vary greatly. In some US States, like in California, applicable environmental standards and legislation are more stringent than in other US states, like Florida. Depending on the desalination technology used and the method of calculation, present costs of water desalination vary between US$ 0.60/m^3 in the Arabian Gulf region, US$ 1.63/m^3 in Australia, and US$ 1.86/m^3 in the United States.[11]

Seawater desalination is an important option for addressing water supply challenges in water-scarce regions. The energy intensity of desalination processes has dramatically decreased from some 15 kWh/m^3 in the 1970s to about 2.5 kWh/m^3 today, thanks in large part to reverse osmosis technology improvements. Whereas desalination may offer local solutions to address the growing freshwater shortages in fossil fuel rich countries of the Middle East, the scenario of rapidly growing global energy (fossil fuel) use for desalination is causing concerns over growing greenhouse gas emissions and accelerating climate change.

The Global Knowledge Platform on Sustainable Water and Energy Solutions may include case studies on desalination and renewable energy use, and it may also consider designating a focal point as an expert to facilitate collaborative information exchange on this topic.

Efficiency of energy use in water supply and distribution systems

Water supply, treatment and distribution, as well as wastewater collection and treatment are typically in the domain of municipalities and public enterprises. The two primary sources of water for drinking water systems are groundwater and surface water. Groundwater typically has a better quality. Surface water systems require more water treatment than groundwater systems and are thus more energy intensive. Surface water typically contains a high suspended

[10] GWI Desal Data & IDA, www.desaldata.com

[11] For a more info see: https://www.advisian.com/en-gb/global-perspectives/the-cost-of-desalination#

solids content, bacteria, algae, and organic matter.

Two processes are commonly used to treat surface water. Conventional treatment includes clarification, sand filtration, activated carbon adsorption, and disinfection. Advanced treatment includes ultrafiltration technology. Groundwater is also treated to remove iron or other particles. Most drinking water is disinfected (with chlorine) to ensure public health.

Water supply systems require pumping. Where possible, gravity should be used to transport water from where it is to where it is needed. In order to minimize energy use in water supply systems, pumps should be sized appropriately. Installation of variable speed drives whose speed varies to match flow conditions can reduce energy cost. Based on examples of water supply systems in Portugal, it has been shown that energy efficient pumping can reduce energy bill of water utilities by up to 25 per cent (Ramos, H.M., et al, 2012). The use of supervisory controls and data acquisition (SCADA) and hydraulic modelling also offers options for analysing and enhancing efficiency in water supply systems, which so far only some utilities have fully exploited (Walski, T., Andrews, T., 2015).

Water facilities also need to promote water efficiency and conservation, inter alia, by detecting and fixing water leaks in transportation or distribution. Water facilities should also ensure that end users are adequately aware and avoid wasteful forms of water consumption, which will in turn also help to save energy.

Human conveyances, such as (gravity fed) drinking water flows provide opportunities for non-traditional hydropower technology deployment while minimizing civil works and environmental impacts (USDOE, 2014). Highlighting, documenting and collecting data on such type of previously overlooked sustainable water and energy solutions could represent an important part of the content of the Knowledge Platform.

Various sources are available to share information on energy (and water) saving opportunities in water supply and inform relevant decision makers and the concerned engineering community. Under its BlueSCities Programme the European Community has supported the compilation of a comprehensive Compendium of best practices for water, waste-water, solid waste, and climate adaptation (KWR Watercycle Research Institute, 2015). The Global Knowledge Platform may complement these efforts, highlighting the operational, financial and environmental co-benefits of energy efficiency improvement in water supply.

Wastewater collection and treatment systems

Wastewater is a dependable and potentially very valuable water resource. Wastewater could contain nutrients and energy-rich organic carbon. Just as solid waste needs to be separated and recycled, wastewater needs to be collected, and its ingredients separated and recycled.

Wastewater treatment typically requires more energy than water supply. Wastewater needs to be collected and transported to treatment facilities. Like water supply, wastewater transportation should make use of gravity and energy efficient pumps. Wastewater from households and industries contains many contaminants. Several physical, chemical and biological processes are used to remove these contaminants and produce treated wastewater that is safe enough to be released into the environment. Semi solid waste or slurry, also called sewage sludge, is a by-product of the treatment process. Some sludge can be used as fertilizer, or as source for biogas, or, once dried, for on-site incineration and combined heat and power generation (USEPA, 2013).

Sewage plants have high energy needs, and in some cases energy bills can account for as much as 30 per cent of total operating costs. Specific power consumption of state-of-the-art wastewater treatment plants should be between 20 and 45 kWh/person (or population equivalent)/year. Power consumption (per person serviced) is typically lower in large plants serving more than 100,000 inhabitants. Smaller plants have relatively higher specific power consumption. However, with an integrated approach to water treatment, energy efficiency can be improved in almost all facilities. In some cases, wastewater treatment plants have even been converted from net energy users to net energy producers. Some of the most essential measures to enhance efficiency in wastewater treatment are presented here below:

- Storm water and wastewater collection should not mix. Separate piping systems are needed to avoid drainage of storm water into sewerage treatment plants. Rainwater does not need to be treated the same way as wastewater. "Green" infrastructure and buildings can catch and use rainwater, or allow it to drain into the soil.
- Aeration systems typically account for about half of a wastewater treatment plant's energy use. The use of improved system controls, energy-efficient blowers, and energy-efficient diffuser technologies can reduce energy costs in this area (USDOE, 2014).

- Larger water treatment plants can recover biogas or dried sludge from sludge digesters which can be burned in small-scale on-site Combined Heat-and-Power (CHP) Plants.

- One other measure to save energy is to avoid "over-treatment" of wastewater. Various industrial or agricultural users can re-use wastewater that is only partially treated, thus avoiding the cost that a complete treatment would otherwise have required.

- Many technical options are available to economically recover heat from wastewater, even on a small scale. Heat can be used on-site or marketed in the vicinity.

With globally growing awareness of micro-plastics pollution treatment of wastewater will quite likely become more challenging and more energy-intensive in the future.

In spite of its importance for sustainable development, wastewater treatment has failed to attract the necessary public or political attention. Modernization of wastewater treatment facilities is thus often rather slow. Studies have shown that there remains a large potential of unused opportunities to improve energy efficiency in wastewater treatment, and to produce green heat and power from these sources, simultaneously reducing greenhouse gas emissions in the process (UN Water, 2015). The Global Knowledge Platform may be used to publicize such options with a view to promote a further path to sustainable development.

6.3 Meeting basic water and energy needs of the urban and rural poor –Leave No One Behind

Integrated planning and decision making is not only important at the national, macro-economic, state or city level, but also in the context of addressing urban and rural poverty. Globally an estimated 2.1 billion people lack access to safely managed drinking water and almost 1 billion people still have no access to electricity (IEA, 2018). In most cases, people lack access to both water and sustainable energy services, particularly in rural areas and peripheral urban areas, where infrastructure and health services, as well as access to education, is often also missing (UNDESA, 2014).

"Leave No One Behind" is one of the major concerns reflected in the 2030 Agenda for Sustainable Development. Today, the poorest segments of the population are usually the ones who lack the three basic services of energy, water and sanitation. About two-thirds of people in rural areas who lack access to clean drinking water also lack access to electricity. The 2020 COVID19 pandemic and health crisis call for effective actions and international cooperation to ensure access to these critical services. Integrated water and energy solutions represent innovative and efficient options to provide these critical services to the people who need them the most. Technological innovative systems exist and can be developed to realize the synergies that can be derived from integrated approaches to water and energy especially designed to respond to the needs of poor communities.

Water and energy are generally not separate needs; together they represent the core challenges faced by many households, communities, institutions and small businesses at local level in developing countries. Thus, it is encouraging to see that more and more projects seek to advance sustainable rural socio-economic development as a whole and attempt to pursue an integrated approach, including on the water-energy-nexus.

Decentralized renewable energy systems are pivotal for poverty reduction and integrated rural development. Off-grid integrated water and energy solutions are playing an increasing role in isolated communities. Integrated water and electricity approaches could also be based on mini-grids or grid-connected systems where water could allow power generation and help with energy balancing and storage. Small-scale rural hydropower generation (using water for energy) offers proven concepts for providing access to electricity at low costs enabling electricity supply to rural villages, schools and clinics. The small-scale rural hydropower potential is particularly good in mountainous or hilly regions of (sub)tropical developing countries which often have an abundance of water. Other rural poverty reduction projects have successfully introduced renewable energy use for pumping water and as a source of electricity for lighting, communication and information purposes. In many developing countries a variety of projects use wind or solar power to operate small-scale water pumps that improve local communal drinking water supply or power small-scale irrigation systems.

An innovative approach being promoted is the development of "energy-water in a box" solutions that are modular, portable, reliable and cost effective. Small modular energy-water systems have the potential to serve areas where energy and water are scarce, expensive or challenging to obtain. These systems are particularly useful as a response to catastrophic events such ad the COVID-19 pandemic and other disasters resulting from climate change affecting communities in isolated areas and islands. The reliability, portability and speed of deployment are key characteristics for the effectiveness of these systems during unexpected events (USDOE, 2019) (UNDP, 2020).

The value and the advantages of integrated planning and decision making on water and energy is increasingly recognized. However, it has not reached the "mainstream" as yet. With reduction and eradication of poverty firmly enshrined in the 2030 Agenda, the Global Knowledge Platform may play an important role by collecting and publicizing information and profiles of selected successful integrated water and energy projects that have been implemented in developing countries in recent years, contributing to improved local living conditions in rural areas. The Knowledge Platform may serve as a mechanism to encourage and support the mobilization of technical and financial resources to advance international development cooperation in this area.

7. Operationalizing the Global Knowledge Platform

The Global Knowledge Platform will serve as a source of reliable data and statistics that will support an enabling environment for the acceleration of integrated sustainable water and energy solutions. The information will enable innovation and research on relevant technologies and will facilitate education, training and access to specific information on experiences that are benefitting from synergies resulting from integrated water and energy programmes. Additionally, the database will facilitate access to information related to challenges, lessons learned, and good practices derived from these experiences. The Network may also consider to periodically organize international information sharing and capacity building conferences and training events for which the Platform may be used to disseminate announcements, reports, outcomes, and recommendations.

The online Global Knowledge Platform will be designed to ensure a fully user-friendly interphase. Pages will be designed for a comprehensive logical approach that will be menu driven. The website of the Platform is proposed to include weblinks to other existing nexus platforms, so as to ensure widest possible outreach. The Global Knowledge Platform is proposed to be interconnected with the UN Sustainable Development Platform serviced by UNDESA. The Global Knowledge Platform is proposed to be accessible free of charge for general public, except for a restricted access area reserved for communications among members and associates only.

The Global Knowledge Platform on Sustainable Water and Energy Solutions could be structured to include eight main areas of spaces for the following subjects: (1) coordinated global efforts and international cooperation; (2) national policies, regulatory considerations and institutional arrangements; (3) asymmetries; (4) data issues; (5) modelling and analytical tools; (6) gaps; (7) Means of Implementation (financing, capacity development, technology transfer); and (8) most promising technology areas and innovative systems.

The Priority Content of the Knowledge Platform could be about the emerging potential core of integrated innovative systems and technologies supporting sustainable water and energy solutions that offer the best opportunities to realize synergies and efficiencies and that could more effectively support the global goals on sustainable development and climate change. The Priority Content could be dedicated to the inventory of leading projects, initiatives and practices on the crucial water-and-energy technological areas and systems identified as priorities in this Scoping Paper.

The proposed categories to be considered in the Priority Content of the on-line structure of the Global Knowledge Platform could include in relation to water consumption in energy systems: hydropower generation from surface reservoirs, and options for operational efficiency improvements; run-of-river hydropower generation and options for rehabilitation, efficiency improvements, and additional capacity; energy storage; ocean energy; water-based cooling systems in thermoelectric power plants (once-through, recirculation, and dry cooling of coal-, gas, and nuclear plants)and potentials for their improvements; geothermal energy use for heat and electric power production; bioenergy; and hydrogen. With regard to energy consumption in water systems, the Global Knowledge Platform may cover: desalination of (sea)water using renewable sources of energy; drinking, industrial and agricultural water supply and distribution systems and options for expanding capacities and enhancing energy efficiency; and wastewater collection and treatment systems, efficiency improvements, renewable energy generation from wastewater, and additional capacity development in developing countries. The Global Knowledge Platform may provide information and analysis on decentralized small-scale projects designed to meet basic water and energy needs of the urban and rural poor in developing countries in an integrated manner.

The management of the Global Knowledge Platform and its database or collection of case studies will monitor and edit the content. The quality of the selected case studies is more important than quantity of the materials. The Sustainable Water and Energy Solutions Network may designate interested "focal points" from among its members to provide editorial guidance for the development of the case study profiles in selected categories.

To facilitate the launch of the Global Knowledge Platform and its subsequent development, a proposed standard format for the case studies and project profiles is attached in Annex 1. Project profiles accepted for inclusion in the database/inventory of case studies may include referrals to further sources of information including more detailed company or project reports, websites, or contact addresses.

As the Global Knowledge Platform and its inventory of information on the water and energy nexus and the related projects, initiatives and experiences develops, the Sustainable Energy and Water Solutions Network will gain increasing international recognition. With time, the Network and its Global Knowledge Platform will make an increasingly important contribution to advance sustainable development and to move implementation of integrated and effective water and energy projects forward, whilst protecting the global climate.

Annex I – Suggested Baseline Reporting Format for Case Studies and Project Profiles

Sustainable Water and Energy Solutions Network
Case study – Project title

Selected photos for illustration of Case Study documentation

Name of Institution or Company
Location of Project Site, Country

Brief Narrative Objective/Description of Project/Activity/Initiative
Economic, Environmental and Climate Benefits/ Challenges/Lessons Learned
Including impacts on specific target groups from the project
Additional Information: Website Addresses and Contacts

This compendium of twenty selected case studies exemplifies activities and experiences using integrated systems and approaches to water and energy. The case studies cover different world regions and different integrated technological systems designed and implemented for different purposes and objectives. Some of them represent innovative approaches and systems that still are being demonstrated but have potential for future use. Others provide enhancements and added efficiencies that support more effective management of water and energy resources following an integrated approach.

These preliminary case studies follow the format for summary case studies proposed by this Scoping Paper.[12] This format allows users of the Global Knowledge Platform to get a glance of projects, programmes and activities, each summarized in only two pages. Eventually, it is expected that the Platform will include many case studies like the ones included in this compendium, classified according to different factors.

The case studies illustrate how synergies can be realized taking into consideration the strong interdependence that exists between water and energy. Some of these projects and experiences provide opportunities to accelerate global climate change objectives and to tackle the critical issues of access and reliability, especially for the effective planning and response to emergency situations and world crises such as pandemics.

[12] The sources for the photos in this compendium are dully acknowledged. For some of these photos, the Secretariat of the Network is still in the process of getting permission for their use.

Case Study 1: Generating Hydropower through Sustainable Management of Natural Resources. (ITAIPU Binacional, Brazil / Paraguay)

Photos by Itaipu Binacional

Organization, Institution or Company
Itaupu Binactional
Location of Project Site, Country
Foz de Iguazu, Brazil, and Ciudad del Este, Paraguay

Brief Narrative Description of Objective/ Project/ Activity/ Initiative

Itaipu Binacional is an organization created in 1974 by the Governments of Paraguay and Brazil in order to utilize the Parana River to generate hydropower. The Itaipu Hydropower Plant is the largest generator of renewable power in the world with a record annual generation of electricity of 103.1 million MWh in 2016 and a total installed capacity of 14,000 MW. In 2018, Itaipu generated 90 per cent of the electricity consumed in Paraguay and 15 per cent of the electricity consumed in Brazil. The reliance on clean and efficient electricity is greatly contributing to the relatively decarbonized economies of Paraguay and Brazil avoiding large volumes of GHG emissions throughout its 35 years of continuous operation.

The Itaipu reservoir contains 29 billion cubic meters of water with about 135,000 hectares of water surface. The reservoir is not only used for electricity generation but also for agriculture, fishing, aquaculture, touristic and leisure purposes and as a municipal water source and for maintaining wildlife and ecosystem services in the relevant area in both countries. Itaipu leads many activities designed to conserve and maintain the quality and conditions of all these water-related ecosystems at optimum levels. In relation to terrestrial ecosystems, about 101,000 hectares of forests surround the Itaipu reservoir. This area represents the protected belt for the reservoir along the Brazilian and Paraguayan margins. Itaipu manages within this area a total of 10 protected areas including biological sanctuaries and reserves that protect native flora and fauna and advance research and conservation initiatives. These areas and the reservoir provide valuable connections among important remnants of the Atlantic Forest located in Paraguay, Brazil and Argentina.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

Itaipu is currently embarked in a comprehensive technological update and upgrade of its power plant and substations designed to enhance energy efficiency and reliability while reducing costs. This effort includes the digitalization of all the electricity generation and control systems. This modernization process will allow Itaipu to achieve higher levels of energy efficiency and consequently higher efficiency in the use of water.

Itaipu contributes to the global efforts on combating climate change and its impacts. The electricity generation from the Itaipu Hydropower Plant replaces the equivalent of 550,000 barrels of oil or 50 million cubic meters of natural gas each day. Itaipu is avoiding the emissions each day of about 87 million tons of CO_2 equivalent if it is replacing coal and 39 million tons of CO_2 equivalent if it is replacing natural gas. The GHGs fixation by the vegetation of the protection belt and wildlife refuges is estimated at 5.9 million tons per year.

The sustainable development strategy of Itaipu and its comprehensive program of activities related to climate change coupled with the optimum integrated management of water resources and protection of water and terrestrial ecosystems represent an excellent example of an integrated approach to sustainable development and climate change.

Additional Information: Website Addresses and Contacts

ITAIPU Binacional. (2019). *Ensuring Availability and Sustainable Management of Water and Sanitation for All, Case Study: Itaipu and SDG 6.* Paraguay.
ITAIPU Binacional. (2019). *Ensuring Access to Affordable, Reliable, Sustainable and Modern Energy for All, Case Study: Itaipu and SDG 7.* Paraguay.
ITAIPU Binacional. (2019). Sustainability Reports
https://www.itaipu.gov.br/en/social-responsibility/sustainability-reports

Itaipu initiatives on rural development and incomes, aquaculture, biodiversity protection and sustainable tourism

Case study 2: Sustainable desalinations, renewable energy and energy storage in the Canary Islands. Canary Islands Institute of Technology, (Canary Islands, Spain)

Photos by ITC and Ministerio para la Transicion Ecologica, Spain.

Organization, Institution or Company
Canary Islands Instituite of Technology (ITC)
Location of Project Site, Country
Canary Island, Spain

Brief Narrative Description of Objective/ Project/ Activity/ Initiative

Several regions of the world are experiencing an increasing shortage of drinking water. Seawater desalination promises to provide local solutions. However, in many cases seawater desalination is powered by fossil fuels, and thus potentially expensive, also contributing to increasing GHG emissions.

The group of the Canary Islands of Spain include the islands of Lanzarote, Fuerteventura, El Hierro, Gran Canaria, Tenerife, La Gomera, and La Palma. Over the years, the islands have developed a combined desalination capacity of 731,000 m^3/day, which is equivalent to 2 per cent of total global desalination capacity. A large portion of the desalinated water is provided to service the tourism industry.

The Canary Islands archipelago in Spain provides an excellent example of how a region with water shortage can alleviate its local water scarcity problem. The Canary Islands Institute of Technology (ITC) has demonstrated that reverse osmosis desalination technologies can be powered by renewable energy. Water desalination can be performed in an economically feasible way with electrical energy provided by sun and wind. Additionally, intermittent energy supply can be backed up with hydropower storage.

ITC, a public enterprise established by the Government of the Canary Islands in 1992, has developed and tested various prototypes for off-grid small-scale and larger-scale renewable energy driven desalination systems since 1996. Most ITC's facilities are located in Pozo Izquierdo on Gran Canaria Island. Local conditions are excellent: the site has direct access to seawater, and annual average wind speed of 8 m/s, and average daily solar radiation of 6 kWh/m^2.

At its field project sites, ITC has tested different methods and products of various suppliers using water vapour compression, reverse osmosis (RO), electro dialysis, and membrane distillation. ITC holds its own patents in the area of desalination technology powered by renewables

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The ITC projects suggest that desalination stations should be designed and tailored to meet the prevailing local conditions. In locations where water demand is limited, e.g. up to 100 m^3 /day, the most feasible option may be the use of solar-PV-powered RO systems. For locations with medium or larger water demands (1,000–5,000 m^3 /day), the more suitable systems may be combined off-grid wind farm and reverse osmosis plants. The installation of automated controls is important to reduce maintenance costs. Desalination technology based on renewable energy avoids the release of greenhouse gas emissions during operations.

In some locations, the disposal of brine resulting for the desalination process can pose a challenge. Brines can be returned to the sea, but need to be diluted to prevent local environmental impacts.

International cooperation

ITC offers training and advisory services to support and guide developers of desalination projects, particularly from developing countries, to design their own sustainable solutions.

ITC has helped designing a desalination plant powered exclusively by photovoltaic solar energy that supplies drinking water to rural areas in Mauretania. The installation has been operational since 2006 and is based on the autonomous desalination technology developed by ITC, called DESSOL®, which has an international patent.

Additional Information: Website Addresses and Contacts

Canary Islands Institute of Technology (ICT) https://www.itccanarias.org/web/en/

de la Fuente, J.A., Water Department, Canary Islands Government: https://www.gwp.org/contentassets/aa500f6c8cb749d7ac324a4065395386/203.the-canary-islands-experience.pdf

International Energy Agency (IEA)/International Renewable Energy Agency (IRENA): https://iea-etsap.org/E-TechDS/PDF/I12IR_Desalin_MI_Jan2013_final_GSOK.pdf

Case study 3: Water, biomass and energy nexus: electricity generation from sugarcane biomass in Guatemala: Association of Sugar Producers of Guatemala (ASAZGUA)

Photos by Asazgua Association and ICC

Organization, Institution or Company
Association of Sugar Producers of Guatemala (ASAZGUA)
Location of Project Site, Country
Guatemala

Brief Narrative Description of Objective/ Project/ Activity/ Initiative

Guatemala's economy increasingly depends on export oriented agriculture with sugarcane and sugar production playing a leading role. Sugar factories have used bagasse for power generation since the 1990s. Sugarcane is also the main agricultural base for ethanol / biofuel production. With growing domestic and international demand and competition for land, water and energy understanding their interlinkages and identifying opportunities for synergies and efficiency is of great importance in Guatemala. The Association of Sugar Producers of Guatemala (ASAZGUA) and the Private Institute for Climate Change Research (ICC) of Guatemala have undertaken important research in this field.

Guatemala faces considerable challenges in terms of water resources management. Several parts of the country suffer from water scarcity. Public investment in water infrastructure and services is often low. However, there has been significant progress in the sugarcane growing regions. Several roundtable multi-stakeholder consultations were organized by local governments to facilitate dialogue on water needs and water use between local communities, agro-export companies, governmental organizations, and municipalities

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The average water footprint of sugarcane cultivation in Guatemala is estimated at some 129 m^3 of water per ton of sugarcane, which is 38 per cent below world average. Some 72 per cent of the water used for the sugarcane crop in Guatemala is provided by rainfall and 22 per cent by irrigation from surface and underground sources. Sugarcane cultivation in Guatemala covers around 260,000 hectares, and 80 per cent of this land is irrigated, leading to concerns about the impact of the industry on water resources. However, sugarcane plantations and sugar mills have been taking many initiatives over the past 20 years to increase the efficiency of irrigation. This includes research, investment and installation of efficient irrigation technology. There have also been many efforts to reduce the water footprint in the sugarcane mills through improvement of efficiency, water re-use, and the elimination of washing of cane.

Electricity from sugarcane biomass (bagasse) in Guatemala is a significant component of the energy matrix. Sugar companies started generating electricity from bagasse in the 1990s to meet own needs and to sell to the grid. During the past five years (2014 to 2018) the contribution of the sugar industry to annual power generation accounted for 10.7 to 18.1 per cent. Power generation from bagasse is typically seasonal from November to April. It complements electricity generation from hydropower, which is typically low during the same period.

Total electricity generated from sugarcane biomass has increased substantially from around 400 GWh during the 1997-1998 harvest season to 2,500 GWh in the 2017-2018 harvest season. This increase has resulted from growth in cultivated area, and from achieving higher efficiency in biomass-based power generation. Sugar companies in Guatemala use about 34 per cent of the electricity they generate for their own industrial processes, especially sugar production. The remaining 66 per cent is sold to the national grid.

In Guatemala, during the harvest season biomass from sugarcane can in part replace the use of coal for electricity generation. During the harvest season 2017-18 around 3.8 million tons of CO_2e were avoided through the use of bagasse. The carbon footprint of electricity from sugarcane biomass averages some 0.24 kg CO_2e/kWh (2019), whereas the overall national average is about 0.367 kg CO_2e/kWh (2017).

Ethanol from sugarcane can potentially make an important contribution to reduce national GHG emissions in Guatemala. According to the National Low Emission Development Strategy, a 10 per cent blend of domestically produced ethanol in gasoline may help to reduce emissions from motor vehicles, improve air quality in towns and cities, reduce gasoline imports, and help the country accomplish the Paris Agreement. The reduction potential is estimated at some 233,333 tons CO_2e/year.

Additional Information: Website Addresses and Contacts

Private Institute for Climate Change Research (ICC, 2019): Inventario de emisiones de Gases de Efecto Invernadero (GEI) de la generación de energía eléctrica de la Agroindustria Azucarera de Guatemala; Zafra 2017-2018. 9 P.

ICC (2019): Estrategia de Reducción de Emisiones de Gases de Efecto Invernadero -GEI- en la Producción de Azúcar de Guatemala. 70 P.

Case 4: Integrated water and energy solutions for irrigation in rural India. (proposed by TERI)

Photos: by EESL https://www.eeslindia.org/content/raj/eesl/en/Programmes/Solar/photo-gallery.html

Organization, Institution or Company
Energy Efficiency Services Ltd, a Public Sector Company under Ministry of Power. Case study recommended by TERI
Location of Project Site, Country
India

Brief Narrative Description of Objective/ Project/ Activity/ Initiative

India's agricultural sectors consumes close to 20 per cent of electricity in the country. However, in many parts of the country consumption of energy and water is hugely inefficient. In many agricultural areas, farmers are heavily subsidized or not billed for the electricity use in agriculture and water pumping for irrigation. Water leakage is also high in many irrigation systems, further aggravating the problem. The traditional agricultural sector relies on old and inefficient pumps for irrigation. Most farmers cannot afford modern pumps. Inefficient pumps consume much energy and require frequent expensive repairs.

During recent years, Energy Efficiency Services Ltd, a public sector company of the Government of India, implemented a comprehensive agricultural demand side management programme. The programme includes various measures. One programme element seeks to advance the use of solar PV mini grids for daytime agricultural pumping. Another programme element seeks to disseminate domestically manufactured high efficient pumps.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The programme offers farmers to replace old pumps with modern energy efficient ones, which can save energy, and be operated by remote control thus only using water when really needed. Under the programme, farmers pay for the new pumps in instalments which are the same or lower than their electricity bill savings. The programme provides win-win-win solutions, saving energy and water, whilst also reducing GHG emissions from the agricultural sector. Farmers who install solar PV for powering irrigation pumps will be allowed to sell any excess electricity to the grid of the local distribution companies (subject to availability of a grid connection).

Some estimates suggest that farmers in India may be operating as many as 20 million inefficient pump sets. The more of these pump sets are replaced the higher the energy efficient gains. Estimates suggest that India could realize electricity savings in the agricultural sector alone equivalent to as much as 4,300 million kWh. As electricity for farmers is subsidized the Government could, over time, realize some US$3,100 Million equivalent in public subsidies. The agricultural demand management programme will also have significant environmental benefits as it could mitigate potential GHG emissions estimated at nearly 35 million tons.

Additional Information: Website Addresses and Contacts

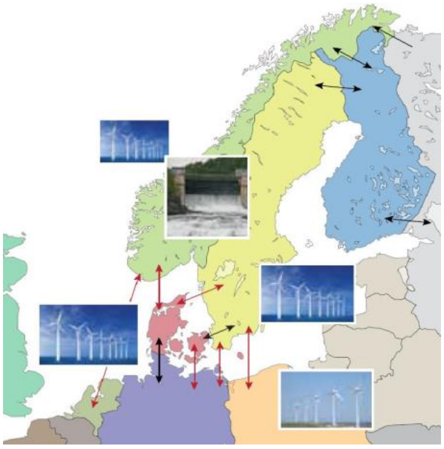
Energy Efficiency Services Ltd website:
https://www.eeslindia.org/content/raj/eesl/en/home.html

Prayas Energy Group (2018): Understanding the electricity, water, agricultural linkages
http://www.indiaenvironmentportal.org.in/files/file/Understanding%20the%20Electricity,%20Water%20&%20Agriculture%20Linkages.pdf

Photos by EESL https://www.eeslindia.org/content/raj/eesl/en/Programmes/AgDSM/photo-gallery.html

Case study 5: The HydroBalance Project: Energy storage from hydropower in Norway supporting intermittent renewable electricity generation in Europe (CEDREN/SINTEF)

Project sketch, permission to be obtained from CEDREN



Organization, Institution or Company
The Center for Environmental Design of Renewable Energy (CEDREN) is developing the HydroBalance Project. CEDREN main partners include SINTEF Energy Research (Norway), Norwegian Institute for Nature Research (NINA), and Norwegian University of Science and Technology (NTNU).
Location of Project Site, Country
Norway

Brief Narrative Description of Objective/ Project/ Activity/ Initiative
The goal of the HydroBalance project is to assess the feasibility of using Norwegian hydropower storage capacities for supporting a better, more efficient and affordable integration of intermittent renewable electricity generation in Europe. The work combines technological, environmental and social science. The HydroBalance Study has shown the value of energy storage from hydropower if compared to other options for storage such as natural gas and batteries. A model was developed assuming a scenario of existing and potential future additional hydropower capacities in Norway and possible additional power systems interconnections. A very accurate wind and solar power output model was developed for Europe. Results from simulations show that availability of energy storage capacities of 23 TWh could help to make the European electricity system emission free by 2050.

Norway presently has 32 GW installed capacity in the hydropower system and 85 TWh reservoir storage, providing 97 per cent of its own electricity supply. Studies have shown that it is possible to develop additional 20 GW of new capacity in the Norwegian hydropower without construction of additional reservoirs.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The goal of the HydroBalance project is to assess the feasibility of using Norwegian hydropower storage capacities for supporting a better, more efficient and affordable integration of intermittent renewable electricity generation in Europe. The work combines technological, environmental and social science.

Additional hydropower storage capacity offers an alternative to expensive capacities for peak thermal power generation. Comparing cost of new gas-power plants located in Europe versus costs of additional pumped-storage in Norway shows that the latter option would be more cost-effective for the provision of peaking capacity. The CEDREN/SINTEF study calls for further dialogue and information exchange to evaluate technical options and their potential economic and environmental benefits.

Additional Information: Website Addresses and Contacts

CEDREN website: https://www.cedren.no/english/Projects/HydroBalance

Photo by CEDREN

Case study 6: Sustainable Hydropower Plant at Reventazón River in Costa Rica and Biodiversity Protection - Case study provided by International Hydropower Association (IHA)

Photos by Reventazon HPP by ICE

Organization, Institution or Company
Instituto Costaricense de Electricidad (ICE), Costa Rica
Location of Project Site, Country
Costa Rica

Brief Narrative Description of Narrative/ Project/ Activity/ Initaitive

Costa Rica's National Power Company (Instituto Costarricense de Electricidad, ICE) planned and built the Reventazón Hydroelectric Dam and Power Station between 2012 and 2016 on the Reventazón River in Limón Province, Costa Rica. With a height of 130 m and 8 km long reservoir holding 3 million m^3 of water, Reventazón is the largest hydropower project in Central America. The power station has an installed capacity of 305.5 MW, sufficient to provide power for some 525,000 homes.

Reventazón was partially funded by the Inter-American Development Bank (IDB) and the International Finance Corporation (IFC) and planned to meet all essential hydropower sustainability criteria. Villagers that needed to be resettled were fully compensated, with programmes ensuring improved livelihoods.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

During the planning phase, comprehensive studies were undertaken to assess the potential impact of the project on Costa Rica's rich biodiversity. In order to protect the unique flora and fauna of the region, ICE, IDB, and IFC developed and realized a biodiversity protection "off-set approach" by way of implementing a comprehensive programme to protect water quality and environmental characteristics at a similar nearby free-flowing riverine habitat, including the Parismina and Dos Novillos rivers.

The programme involved some 16 communities and more than 6,500 residents, many of whom were small-scale farmers. The programme included measures to promote sustainable agricultural practices, development of local plant nurseries, reforestation, improved water resources management, as well as measures to reduce erosion, sedimentation, and pesticide use in agriculture, and the related run-off.

The regional environmental protection programme also included measures of zoning to separate farmland from nature conservation areas, and to re-establish and protect biological (sub)corridors that enable the migration of wildlife, including Jaguar, as well as migratory aquatic species. The biodiversity protection corridors connect the Tortuguero National Park on the Atlantic coast and the central mountain range. Considerable investments were made during the start-up phase, and an annual budgetary contribution of about US$1 million is provided to contribute to recurrent programme implementation costs.

The Reventazón Hydropower Plant in Costa Rica has been named the winner of the 2019 International Hydropower Association Blue Planet Prize, a prestigious award which recognises excellence in sustainable hydropower development.

Additional Information: Website Addresses and Contacts

Sources: The case study is featured in the IHA publication: *Better Hydro: Compendium of Case Studies 2017*, and on the IHA website: https://www.hydropower.org/blog/better-hydro-protecting-biodiversity-at-reventaz%C3%B3n-costa-rica

Reventazón Protocol Assessment Report (Final)
https://static1.squarespace.com/static/5c1978d3ee1759dc44fbd8ba/t/5d7117e2bb767d000140a05c/1567692821693/Reventazon+Assessment+Report+Sept+2017.pdf

IFC website: "Dogs help cats in Costa Rica"
https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/dog+helps+cats+in+costa+rica

Photos by IFC

Case study 7: Desalination through sustainable water and energy solutions in West Asia

Case study provided by Economic and Social Commission for West Asia (ESCWA)

Photo: Aerial photo of Advance Water Technology (awatertech.com) desalination plant at Al Khafji, Saudi Arabia (photo by Siemens Austria)

Organization, Institution or Company
Various public and private sector corporations
Location of Project Site, Country
Various locations in the West Asia region

Brief Narrative Description of Objective/Project/Activity/Initiative
Water desalination is a crucial process for the countries of the Economic and Social Commission for Western Asia (ESCWA) region which have very limited access to freshwater resources. Therefore, rapid increases in installed desalination capacity have taken place in the last two decades.
Economic, Environmental and Climate Benefits, Challenges and Lessons Learned
Historically, thermal desalination has been the dominant desalination technology used, but reverse osmosis membrane-based technologies have been developing rapidly and are currently favoured for new plants. The reverse osmosis systems are considered very effective for sea water desalination but rely heavily on electricity. Though desalination in general is an energy-intensive process, by powering it with renewable energy, some of its drawbacks can be overcome. In addition, renewable energy desalination has the advantage of reduced GHG emissions. Renewable energy desalination plants are operational in Egypt, Jordan, Morocco, and the United Arab Emirates (UAE), but they are mostly of pilot size and do not amount to full

utility scale production. In Dubai, an operational PV solar-powered RO desalination station, at the Mohammed bin Rashid Al Maktoum Solar Park, delivers 50 m^3 per day.

Currently, Al Khafji reverse osmosis membrane desalination plant in Saudi Arabia is planned to be the world's first large-scale photo-voltaic (PV) solar-powered desalination plant. The plant is owned and operated by Advanced Water Technology (AWT) of Saudi Arabia, is a newly formed subsidiary of TAQNIA, the commercial arm of King Abdulaziz City for Science & Technology (KACST). This plant is designed to deliver 60,000 m^3 of desalinated seawater per day in its Phase I, ensuring a regular supply of water to the surrounding province the whole year round. A possible future expansion may increase the capacity to 90,000 m^3/day. The desalination facility will be powered by a 15 MW advanced solar power plant with automatically adjustable PV panels which change their position during the day to optimize the use of solar radiation. The use of solar energy allows the mitigation of a considerable volume of GHGs that would be generated if fossil-fuel generated electricity were used.

Renewable energy desalination plants represent a very promising sustainable water and energy solution for the ESCWA region where water resources are limited, by solar radiation is plentiful. Many research and development efforts are being conducted all over the world to continue improving the efficiency and reducing the cost of this integrated sea-water purification and renewable energy systems.

Additional Information: Website Addresses and Contacts

Related ESCWA Publications:
ESCWA (2017): Water-Energy Nexus Operational Toolkit: Technology Transfer Module
https://www.unescwa.org/publications/water-energy-nexus-technology-transfer-module
ESCWA (2017): Water-Energy Nexus Operational Toolkit: Renewable Energy Module
https://www.unescwa.org/publications/water-energy-nexus-renewable-energy-module

Advanced Water Technology Company, Saudi Arabia:
Company Profile: https://www.awatertech.com/
Company Projects: https://www.awatertech.com/projects
Promotional/educational Video Clip: https://www.youtube.com/watch?v=RYRuQCMG1Uk

Photo from **Siemens AG Österreich, Ms.** Kerstin Glatz-Krainz (Karin-kerstin.glatz-krainz@siemens.com) or Mr. Walter Sattlberger (Walter.sattlberger@siemens.com)

Case study 8: Generating clean electricity and contributing to climate change mitigation goals: The Rogun Hydropower Plant, Tajikistan

Photos from Ministry of Tajikistan and World Bank

Organization, Institution or Company

Ministry of Energy and Water, Government of Tajikistan (Project Management Group for Energy Facilities Construction under the President of the Republic of Tajikistan)

Location of Project Site, Country

Rogun, Republic of Tajikistan

Brief Narrative Description of Objective/Project/Activity/Initiative

In Tajikistan, decision making on energy and water falls under the authority of the Ministry of Energy and Water Resources of the Republic of Tajikistan. The country relies primarily on hydropower for its electricity generation.

Tajikistan is building the Rogun Hydropower Plant which will be the biggest hydropower plant in Central Asia. The Rogun plant is planned to include six hydraulic units with a capacity of 600 MW each and the total capacity of 3,600 MW. Its average annual electricity generation is expected to exceed 17.0 billion kWh per year. Its first unit was launched in 2018 and the second one was commissioned in September 2019.

The Rogun hydropower complex is designed as a multi-purpose dam for generating electricity, regulating water, and reducing the risk of floods and droughts. The Rogun HPP will produce sufficient environmentally friendly and clean electricity to fully satisfy Tajikistan's electricity demand. It will also generate enough electricity to export to neighbouring countries which presently use mostly fossil fuels for electricity.

In 2014, the World Bank approved a package of US$ 526.5 million in grant and credit financing for the Central Asia South Asia (CASA) Electricity Transmission and Trade Project which will interconnect the electric power supply systems of Tajikistan, Kyrgyzstan, Afghanistan and Pakistan.

Economic, Environmental and Climate Benefits, Challenges, and Lessons Learned

In Central Asia, some parts of the sub-region are rich in water resources, but poorly endowed with conventional energy from fossil fuels; whilst other parts of the sub-region are rich in energy resources but suffer from a chronic shortage of water for agriculture and human consumption. The Governments of Central Asia sub-region actively participate in the relevant international and sub-regional consultative mechanisms with a view to coordinate the planning, development, and maintenance of the national and regional water and energy infrastructure and the day-to-day management of the energy and water resources.

The Rogun Plant represents a sustainable water and energy solution contributing to global mitigation goals and regional adaptation objectives. It will provide a valuable contribution to the reduction of the CO_2 emissions in the region.

In addition, the Plant will help to create new jobs and businesses improving the social and economic situation in Tajikistan and neighbouring countries and supporting the sustainable development goals.

Additional Information: Website Addresses and Contacts

Ministry of Energy and Water, Government of Tajikistan https://www.mewr.tj

Project Management Group for Energy Facilities Construction under the President of the Republic of Tajikistan (2014): Techno-Economic Assessment Study (TEAS, Phase II), Summary, (June 2014) http://www.energyprojects.tj/images/pdf/iteoen.pdf

Environment and social impact assessment (ESIA) (2014) http://www.energyprojects.tj/images/pdf/prengi.pdf

World Bank Group 2014: Final reports related to the proposed Rogun HPP https://www.worldbank.org/en/country/tajikistan/brief/final-reports-related-to-the-proposed-rogun-hpp
and Baker Tilly Tajikistan, Resettlement Audit of Flooding Zone of Rogun HPP, Stage I:
http://documents.worldbank.org/curated/en/639941545322964729/pdf/133125-RP-P147617-PUBLIC.pdf

World Bank Group (2018): Tajikistan Country Economic Update 2018 - Rogun HPP – Potential Resource for Building Human Capital
http://pubdocs.worldbank.org/en/624741547182513272/Tajikistan-CEU-Fall-2018-FINAL.pdf

Case study 9: Resilience of electricity generation from hydropower in Colombia: Coping with the El Niño event and associated drought (2015-2016)

Case study provided by World Energy Council.

Photo by ANDEG http://www.andeg.org/ (or WEC)

Organization, Institution or Company
Asociación National de Empresas Generadoras (ANDEG) and Ministry of Mines and Energy of the Government of Colombia (Case study provide by World Energy Council WEC) ANDEG is a private non-governmental association which include 13 Colombian thermal electricity generating companies
Location of Project Site, Country
Colombia

Brief Narrative Description of Objective/Project/Activity/Initiative
El Niño-Southern Oscillation (ENSO) is the Earth's most important weather-producing phenomenon. During an El Niño event, the surface waters in the central and eastern Pacific Ocean become significantly warmer. Usually dry regions of Peru, Chile, Mexico, and the southwestern United States experience rain and snow; wetter regions of the Brazilian Amazon, Colombia and the north-eastern United States plunge into months of long droughts. The 2015-2016 drought was a 1 in 50-year event and the second strongest in the history of Colombia. Rainfall dropped by 40 per cent below usual, generating severe hydrological drought which persisted until March 2016. This case study explores the context of the power shortage and the role of thermal generators in addressing dynamic system resilience in this specific situation of an extreme weather event in a country highly dependable on hydropower.
Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The Colombian energy mix is made up of hydro-generation plants (77 per cent) and thermal-generation plants (18 per cent). In 2016, the impacts of ENSO included: water levels in dams decreased by 60-70 per cent; increased demand for cooling and refrigeration during the hot El Niño months; an unforeseen fire incident at the largest hydroelectric plant (Central Guatapé) further reduced capacity. There was a 200 MW shortage in April 2016 while at the same time electricity increased by a factor of 8. In order to increase resilience the Ministry launched an energy saving and demand management campaign called "Apagar paga" or "Turn off, pay off", which resulted in a 5 per cent reduction of demand. Other short-term measures included: (a) increase in gas supply with liquefied natural gas (LNG) imported from the Caribbean; (b) imported additional energy from Ecuador via an available interconnection; (c) collaboration between the energy sector and the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) which monitors the weather in Colombia; (d) coordination between the Colombian army and Empresas Públicas de Medellín (EPM); and, (e) fast-tracked licensing to accelerate new thermal power plants. Long-term measures include two new thermal power plants (100 MW natural gas and 260 MW coal) in 2018 and further renewable energy diversification. The experience of ENSO in 2015-2016 shows that Colombia needs to closely monitor the weather with a view to project intensity and frequency of future El Niño and La Niña events. As a part of its resilience strategy, the Colombian grid also needs to have sufficient thermal backup capacity to supplement the low hydraulic productivity during the exceptionally dry seasons. Without these alternative resources, demand may have to be rationed, implying potentially even higher economic costs.
Additional Information: Website Addresses and Contacts
Asociación National de Empresas Generadoras (ANDEG): http://www.andeg.org/ Colombia Ministry of Energy and Mines, Bogota, Colombia: https://www.minenergia.gov.co/tips-de-ahorro-de-energia World Energy Council (WEC) : https://www.worldenergy.org/transition-toolkit/dynamic-resilience-framework/extreme-weather and https://www.worldenergy.org/assets/downloads/El_ni%C3%B1o_Colombia_-Extreme_weather_conditions_SEP2019.pdf

Case study 10: Electricity and Clean Water from integrated, self-contained utility systems in Tanzania

Photo by OffGridBox Inc

Name of Water and/or Energy Project, Institution or Company
OffGridBox Inc and UNDP
Location of Project Site, Country
Tanzania in three districts of Bunda, Ikungi and Busega

Brief Narrative Description of Objective/Project/Activity/Initiative
Twelve integrated, self-contained, modular systems have been installed in Tanzania to enable access to clean water and electricity in three villages. They serve about 24,000 people who previously had no electricity and had to walk around five kilometres every day to get water. They are also being used by health centres and schools. In rural Tanzania 16 percent of people have no electricity and more than 70 percent of the country's 57 million people do not have clean and safe water. The systems, installed with support from UNDP, are manufactured by the OffGridBox Inc a company with offices in Italy, USA and Rwanda. The all-in-one utility system, which is called Off Grid Box (OGB), integrates photovoltaic and wind energy generation, rainwater harvesting for domestic use and family agriculture and sewage sanitation with solar thermal energy. The photovoltaic roof directs rainwater with a gutter in the 1,500 liters lower cistern. A high-efficiency pump with mechanical and UV filters sterilizes the water to be used at home, for animals or in the garden. A timer for irrigation can be added as well as additional water tanks. Self-producing electricity from sun or wind can provide up to 20 kilowatts of power that can be stored safely in batteries or can be used to power local or commercial grids. A solar thermal system heats up the water and is integrated with pellet boilers to heat up the whole building, if necessary. The water-electricity system and all its hardware are inside a 6 ft by 6 ft module.
Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The decentralized systems are particularly valuable for isolated communities where there is no access to water and energy including refugee camps. The modular systems represent a promising solution for scaling access to clean water and renewable energy to the billion people in need across the globe.

The systems are carbon neutral since they harvest rain, sun and wind and emit no carbon dioxide into the atmosphere. The project also helps to address the impact of climate change, which has had a pronounced impact in the Lake Victoria region. The negative effects of climate change disproportionately fall on marginalized and rural communities located in this region.

Women, who carry a disproportionate responsibility for household fuel and water collection as well as food preparation, are also benefitting. It is expected that the project will also stimulate a wide range of economic activity. Tanzania's Ministry of Health has also indicated interest in deploying these systems to health centres throughout the country that lack access to reliable sources of clean, safe water and electricity.

These practical, relatively small and easy to install systems could also be very valuable for areas impacted by natural disasters or world crisis such as pandemics. Natural disasters can happen anytime and anywhere, impacting entire countries, cities and families. Electricity, water, and connectivity are critical services that usually become unavailable when a disaster strikes. These systems could provide power and water to clinics, schools or emergency centres when these services are disrupted. They could represent all-encompassing relief hubs providing communication (WiFi / cellular phones), electricity from renewable energy and clean purified water. The systems are designed, in general, to withstand a cyclone with emergency procedures to be implemented in less than one hour. Additionally, they can be easily transported by truck, boat or helicopter and could be installed in about three hours.

Additional Information: Website Addresses and Contacts

Website of OffGridBox https://www.offgridbox.com
Website UNDP article: https://www.undp.org/content/undp/en/home/blog/2020/in-tanzania--electricity-and-clean-water-comes-from-a-box.html

Photos by OffGridBox Inc and UNDP

Case study 11: Power Generation from Solar Photovoltaic Panels Floating on Water Reservoirs

Innovation and collaboration of China Energy Conservation and Environment Protection Group (CECEP) and Ciel & Terre (France)

Photo by Ciel etTerre https://www.ciel-et-terre.net/project/anhui-cecep-70005-kwp/

Organization, Institution or Company
China Energy Conservation and Environment Protection Group (CECEP) and Ciel et Terre (France)
Location of Project Site, Country
Anhui, China

Brief Narrative Description of Objective/Project/Activity/Initiative

As solar PV panels become cheaper and more widely used for electric power generation, the identification of suitable and available sites can pose growing constraints. Large-scale PV installations require considerable space which is not always available in built-up urban or intensively used agricultural areas. In a growing number of countries power generation companies have turned to the surface of otherwise unused inland water reservoirs and lakes to place PV panels of floating platforms.

In China, the China Energy Conservation and Environment Protection Group (CECEP), a large state-owned renewable energy developer, has partnered with Ciel & Terre Company (France) and recently completed a 70MW floating solar project located at a submerged former coal-mining area in Yongqiao District of Suzhou City, Anhui Province

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

The project uses monocrystalline PV modules manufactured in China. The project spreads across 13 separate islets on an area of 140 hectares and was completed in late 2018. Engineering, procurement, and construction services were provided by China Energy Conservation Solar Technology and the China Energy Engineering Group Shanxi Electric Power Design Institute. The floats were designed in collaboration with a French company (Ciel&Terre).

A separate 18 km long 110V overhead line was built for grid connection of the plant. The floating solar plant is expected to generate more than 70,000 MWh of electricity annually, equivalent to the power consumption of nearly 21,000 households. For a brief period, the project was one of the largest of its kind. However, according to recent reports, the Three Gorges New Energy Company is in the process of constructing a similar facility which may have even twice the capacity of the CECEP project once it is completed.

In a recent report the World Bank highlighted the various advantages of electricity generation from solar PV panels mounted on floating platforms, which include low opportunity costs, reduced evaporation, as well as comparatively low construction, installation, and maintenance costs. The technology is being applied in both industrialized and developing countries, and appears to be particularly suitable for locations where land is comparatively scarce and expensive. Some 70 larger-scale projects of floating PV are presently operational or under construction, but their number is increasing rapidly

Additional Information: Website Addresses and Contacts

CECEP website: http://www.cecep.cn/g3614.aspx

Ciel & Terre France), China Office website: http://cieletterre.cn/

For additional information: World Bank (2018): Where Sun Meets Water (Floating Solar Market Report – Executive Summary) http://documents.worldbank.org/curated/en/579941540407455831/Floating-Solar-Market-Report-Executive-Summary

Case study 12: Sustainable geothermal power generation and heating of greenhouses and spas in Kenya's Rift Valley

Photo of Geothermal wells at Olkaria by GDC

Organization, Institution or Company
Kenya Electricity Generating Company PLC (KenGen) and Geothermal Development Company (GDC)
Location of Project Site, Country
Kenya Rift Valley

Brief Narrative Description of Objective/Project/Activity/Initiative

Geothermal energy is the natural heat stored within the earth's crust. Wells are drilled to tap steam and water at high temperatures (250-350°C) and pressures (600-1200 PSI) at depths of up to 3 km. For electricity generation, steam is piped to turbines which rotate a generator to produce electrical energy. Geothermal heat may also be used for direct heating of residential buildings, or industrial, agricultural, or recreational facilities.

Sustainable geothermal power generation needs water in the form of sufficient rainfall and natural replenishment of groundwater near the heat source and/or a systemic recycling and re-injection of used geothermal water after its heat has been extracted. The careful and complete reinjection of geothermal brines can also help prevent potential thermal and/or environmental pollution in the vicinity of geothermal plans. Geothermal brines can carry contaminants that must not be allowed to pollute surface water, soil or air in the vicinity.

Kenya is well endowed with high temperature geothermal resources most of which are located within the axial of the Kenya Rift valley. Kenya Electricity Generating Company PLC (KenGen) is one of the leading electric power generating companies in East Africa.

KenGen operates several large and small geothermal power stations along the Rift Valley with a combined generation capacity of some 700 MW. At present, geothermal resources account for nearly 40 per cent of Kenya's power generating capacity.

Economic, Environmental and Climate Benefits, Challenges, and Lessons Learned
KenGen's larger geothermal facilities are located close to national parks and natural lakes which ensure natural replenishment of ground water. KenGen's Environmental, Safety & Liaison Section carries out comprehensive pre-investment environmental impact assessments, environmental audits, and monitoring of environmental impacts arising from geothermal development. The Section is responsible for ensuring environmental protection and liaison with the local communities on all aspects of social concerns. Kenya's development plan 'Vision 2030' lays out a policy roadmap to double Kenya's geothermal electricity generation every few years. Managing surface water consumption, maintaining sufficient groundwater reservoirs, and avoiding all potential forms of local pollution will be essential for the country to move forward and make progress towards the fulfilment of the SDGs. In many rural parts of Kenya provision of safe drinking water remains a great challenge. In order to promote socio-economic development throughout the country KenGen established its own KenGen Foundation which among other social projects supports the drilling and upgrading of water wells. Provision of clean accessible water for communities neighbouring its power plants has been one of KenGen's key Corporate Social Investment programs since 2005. KenGen Foundation works with various partners in its social projects, including the Lake Victoria South Water Service Board and Tanathi Water Services Board.
Additional Information: Website Addresses and Contacts
Kenya Power Generation Company (KenGen): https://www.kengen.co.ke/ Geothermal Development Company, Kenya: https://www.gdc.co.ke/

Left) Photo of Geothermal wells at Olkaria by GDC
Right) Photos from KenGen therapheutic spa and KenGen Foundation rural water supply projects

Case study 13: Run-of-River Hydropower Generation: Modernization and capacity expansion at Iffezheim Barrage, Rhine River (France and Germany)

Photos: Aerial view of Iffezheim RoR Plant; and Rotor of Turbine 5 (Photos: EnBW/Daniel Meyer-Gerber) from presse@enbw.com

Organiztion, Institution or Company
Rheinkraftwerk Iffezheim GmbH is co-owned by EnBW Kraftwerk GmbH of Germany and Electricite de France (EDF) of France
Location of Project Site, Country
Iffezheim on Rhine River, France and Germany

Brief Narrative Description of Objective/Project/Activity/Initiative

Several run-of-river power plants are located along the upstream section of the Rhine River which also forms the border between France and Germany.

The Iffezheim barrier is a French-German multi-purpose cooperation project first started in 1970. It was built as a run-of-river hydro power station, with initially 4 horizontal turbines. Turbines have a diameter of 5.8 meters and run at 100 rpm, with a total water flow of 1,100 m^3/second. With a head of 11 meters, Iffezheim is the biggest RoR power plant on the Rhine, and one of the biggest in Europe.

The barrier regulates the water flow and contributes to flood protection. The project also facilitates navigation and shipping on the upper Rhine River. The water gate next to the power station is said to be used by about 45,000 boats and ships each year.

In 2009, the operators agreed to modernize the facility and expand its capacity by adding an additional high-efficiency turbine, bringing the total capacity of the five turbines to 148 MW. The additional turbine was added to the commercial operation in 2013.

Economic, Environmental and Climate Benefits, Challenges, and Lessons Learned

With its modernization and capacity expansion the Iffezheim RoR hydropower plant generates more than 860 million kWh of electricity per year. Its production is sufficient to supply the electricity needs of about 250,000 households in the region. Run-of-river hydropower generation practically does not withdraw or consume any water, as the water flow is immediately returned to the river. Hydropower generation from river flows does not generate greenhouse gas emission during operations. The Iffezheim barrier facilitates efforts to reintroduce species of migratory fish to the Rhine river. The barrier features Europe's largest fish ladder which enables the seasonal migration of fish and addresses important environmental concerns. The Iffezheim fish ladder is 300 m in length, comprises more than 40 interconnected water basins of 15 m^3 each, and provides for a water flow of 1.2 m^3/second. The fish ladder is fitted with a special turbine that oxygenates the river water, attracting migratory species including trout, salmon and eel. Fish can pass the run-of-river hydropower station in both upstream and downstream directions. The Iffeszheim barrier collects any floating debris from the river water. This protects the turbines and helps to clean the river. However, management of sedimentation and preventing riverine erosion can pose challenges for run-of-river hydropower production.
Additional Information: Website Addresses and Contacts
Further technical information can be obtained for EnBW Company website: https://www.enbw.com/renewable-energy/wasserkraft/#content_zeile_8_4___neubauprojekte or by writing to presse@enbw.com Additional information is also available on the webpage of Iffezheim Municipality (only available in French and German): https://www.iffezheim.de/pb/Home/Wirtschaft_Tourismus/Staustufe+_+Kraftwerk.html

Ship at Iffezheim Watergate unloading rotor of turbine 5, and fishladder (Photos EnBW/Daniel Meyer-Gerber): https://www.enbw.com/company/press/download-centre/power-generation/hydroelectric-plants/

Case study 14: Sustainable air-conditioning and water heating/cooling systems of sea-side commercial buildings using seawater: Victoria and Alfred Waterfront, Cape Town, South Africa

Photo: Aerial View of Cape Town by V&A Office of Tourism Office

Organization, Institution or Company
The Victoria and Albert Waterfront (V&A) is jointly owned by Growthpoint Properties Limited and the Government Employees Pension Fund (GEPF), represented by the Public Investment Corporation Limited (PIC).
Location of project Site, Country
Cape Town, South Africa

Brief Narrative Description of Objective/Project/Activity/Initiative

The Victoria and Alfred Waterfront along the old harbor of Cape Town is one of South Africa's most visited destinations. It attracts some 24 million people every year. The V&A Waterfront is a 123-hectare mixed-use residential and commercial property development which caters to both local and international visitors. It includes hotels, retail districts, and extensive dining, leisure and entertainment facilities, as well as several heritage sites and tourism landmarks. The area includes the recently opened Zeitz Museum of Contemporary Art Africa (MOCAA) and the newly upgraded Cape Town Cruise Terminal.

Enhancing sustainability is an important goal at V&A Waterfront. International and national experts were commissioned to design and build a seawater district heating and cooling system for several commercial buildings, including the Museum, hotels and luxury apartment and office buildings. The innovative air and water cooling and heating system uses the seawater of the Atlantic Ocean as heat source and heat sink. During hot summer months, pre-cooled water is created by pumping filtered sea water through plate heat exchangers to a primary pre-cooling water circuit. This water is then pumped on to the various buildings. Separate buildings use their own secondary pumps to pump the pre-cooled water to pre-cooling coils in the air-handling units. High efficiency variable speed and variable flow chillers are used to produce chilled water. The chillers can also produce hot water for winter heating and pre-heated domestic water for washing. Some chillers are designed to produce both chilled and hot water simultaneously. This results in significant electrical savings when both hot and chilled water are required.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

Seawater-based cooling and heating systems may be costly in their installation. However, overall operational costs are comparatively low and fossil fuel-based energy otherwise needed for cooling or heating can be saved by using heat exchangers, condensers, and chillers. Seawater cooling/heating systems vary in their designs. They use seawater either in open loop or refrigerants in closed loop systems. Seawater can serve as heat source and/or heat sink.

Three quarters of the world's megacities are located at or near the seaside. Greater use of seawater for cooling and/or heating of buildings can greatly help reduce GHG emissions. Other projects using seawater for heating or cooling of seaside commercial or residential buildings are in operation in Denmark, Hong Kong (China), Singapore, Sweden, Hawaii (United States), and several of the countries in the Caribbean.

Additional Information: Website Addresses and Contacts

Sources: Information on V&A Waterfront: https://www.waterfront.co.za/wp-content/uploads/2019/08/1804460_VA-_-EIS-Booklet-2018_Digital_Final-1.pdf

Information on seawater-based cooling and heating systems: http://www.improv-air.co.za/index.php/2015/12/13/new-district-cooling-plant-for-va-waterfront-silos/

Case study 15: Generating Hydropower from Water Supply Systems (Melbourne, Australia)

Photos by Melbourne Water

Organization, Institution or Company
Melbourne Water Public Company
Location of Project Site, Country
City of Melbourne, Australia

Brief Narrative Objective/Description of Project/Activity/Initiative

Melbourne Water is a statutory authority owned by the Government of the State of Victoria, Australia. Melbourne Water is responsible for all water supply and wastewater treatment systems in the City of Melbourne and its vicinity. The city's water supply originates from the Yarra River catchment, an area of more than 4,000 km^2 located to the North and East of Melbourne.

Melbourne Water has shown a strong commitment to hydropower generation as part of its overall commitment to sustainability and renewable energy. Water is transferred from major storage reservoirs at higher elevations to smaller service reservoirs at lower elevations, predominantly via gravity. By installing small hydroelectric power stations between the various water reservoirs, Melbourne Water is able to generate renewable electricity, harnessing a natural, sustainable and reliable source of energy.

The first hydroelectric power stations were installed at Thomson Dam (7.4 MW) in 1989 (later upgraded in 2012) and at Cardinia Reservoir (3.5 MW) in 1984. In 2004, Melbourne Water reviewed its network and identified initially six additional sites. Between 2008 and 2010, these six additional mini hydroelectric power stations were constructed throughout the water supply network. During 2016-2017, five more mini hydropower sites were added to the system. The most recently added facilities are located at Dandenong, Wantirna, Mt Waverley, Cardinia Creek, and Boronia. All new plants were delivered in pre-assembled, self-contained units, offering simple, weather resistant power delivery solutions which were brought online quickly. Once the water has been diverted through the power plant it flows back into the water supply system, which feeds the residential water supply network across Melbourne.

Economic, Environmental and Climate Benefits/Challenges/Lessons Learned

Today, Melbourne Water is able to generate more than 69,500 MWh of power per year via hydroelectric generation, which is enough to supply some 14,100 homes. The renewable power generation avoids some 75,800 tonnes of CO_2 emissions, equivalent to taking more than 29,200 cars off the road.

The operation of the eleven mini-hydro plants allows Melbourne Water supply operations to contribute more electricity to the grid than is needed for the operation of the water supply facilities.

All mini hydro plants are fully remote-controlled, operational from offsite, and seamlessly integrated into Melbourne Water's supply system to ensure uninterrupted operation. Melbourne Water's mini hydro plants combine economic and ecological efficiency to produce renewable electricity from sustainable sources.

Additional Information: Website Addresses and Contacts

Melbourne Water Media Contact: https://www.melbournewater.com.au/media/2366

Further information: minihydros@melbournewater.com.au

Photo: Thomson Water Supply Reservoir by Melbourne Water

Case study 16: Energy efficiency and environmental protection in wastewater treatment at the Marselisborg Wastewater Treatment Plant, City of Aarhus, Denmark

Marselisborg Wastewater Treatment Plant. Photo by Aarhus Vand via Thomson Reuters Foundation.

Organization, Institution or Company
Aarhus Vand A/S (Aarhus Water Ltd.) is a public limited company owned by the City of Aarhus, Denmark, which provides water supply and sewerage treatment services.
Location of Project Site, Country
Mareslisborg, Aarhus, Demark

Brief Narrative Description of Objective/Project/Activity/Initiative

In 2005, the Aarhus City Council decided to upgrade and consolidate its municipal wastewater treatment system which at that time comprised of smaller facilities at seventeen different locations. Today, the newly built Marselisborg Wastewater Treatment Plant (WWTP) is the largest in Aarhus, and one of the most modern WWTPs in Denmark, treating an estimated 32 million cubic metres of wastewater annually.

Operations at the Marselisborg WWTP have been optimised over the years by the installation of several components, including a supervisory control and data acquisition (SCADA) system, which controls the levels of ammonium, nitrate and phosphor, and which optimizes the nitrification/denitrification process. New equipment has also been installed to improve efficiency and reduce the cost of aeration in secondary wastewater treatment. In addition, the new on-site combined heat and power station was equipped with three new biogas engines (CHP).

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

By optimising its systems, Marselisborg WWTP became a net power and heat producer. Its annual production of electricity from biogas reached 9,628 MWh in 2015, whilst its own consumption amounted to only 6,311 MWh during the same year.

Today, Marselisborg WWTP produces more than 50 per cent more electricity than its own consumption. It also produces some 2.5 GW of heat for the Aarhus district heating system annually, generates CO_2 emissions savings of more than 150 tons per year, whilst recurrent operating costs are an estimated 40 percent lower than in other WWTP facilities.

The Marselisborg Wastewater Treatment Plant was referenced in the IEA World Energy Outlook 2016 and is widely seen as a best practice model.

The plant has received many visiting delegations as part of international information exchange and capacity building programmes and offer capacity building opportunities for delegations from other countries.

Additional Information: Website Addresses and Contacts

Aarhus Vand website: https://www.aarhusvand.dk/en/international/solutions/tomorrow/ and
https://www.nordregio.org/sustainable_cities/marselisborg-wastewater-treatment-plant/

Photos by Danfoss

Case study 17: Solar powered water desalination for small islands: Rodrigues Island of Mauritius

Organization, Institution or Company

Rodrigues Regional Assembly of the Government of Mauritius, in cooperation with Mascara Renewable Water and Quadran Companies (France) and financial support of Indian Ocean Commission, European Commission, and French Agency for International Cooperation (AFD)

Location of Project Site, Country

Rodrigues Island, Republic of Mauritius

Brief Narrative Description of Objective/Project/Activity/Initiative

The island and the economy of Mauritius in the Indian Ocean is well endowed with water resources. However, some 580 km to the East of Port Louis lies the small island of Rodrigues, which has a population of some 41,000 inhabitants. Rodrigues island is suffering from recurring droughts and natural water resources and rainfall harvesting does not supply sufficient water for the inhabitants. The effects of climate change are noticeable, especially with drinking water becoming increasingly scarce. Residents are forced to travel long distances for water whereas Rodrigues is surrounded by sea water.

The local island authorities started a desalination programme a few years back, which has a significant energy consumption, high operating cost, and significant greenhouse gas emissions. Then, in 2018, Rodrigues pioneered an innovative project with the construction of a solar desalination plant. The plant is producing 80 m^3 of fresh drinking water every day. At night, it uses its grid connection to produce another 300 m^3 of drinking water.

With Rodrigues' inhabitant's average consumption of 125 liters per person per day the solar powered desalination facility can supply drinking water in a reliable way throughout the year to some 2,400 residents in its vicinity, representing a part of the island's population.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

In March 2019, the islands of Mauritius were hit and seriously affected by cyclone Joaninha which passed north of Rodrigues Island and caused serious material damage and major power outages. However, the water desalination plant, powered by solar energy, resumed operation just a few hours after the fierce cyclone. Whereas the solar-powered drinking water supply system showed adequate resilience it took the island several weeks to fully restore the entire power system.

The Mascara Renewable Water and Quadran Companies which provided the equipment and the expertise have demonstrated on Rodrigues Island that solar powered desalination systems may offer sustainable water and energy solutions that may also be suitable and affordable for other remote communities on the African continent and in the Indian Ocean region.

Additional Information: Website Addresses and Contacts

Ministry of Foreign Affairs of Republic of Mauritius (2019): Voluntary National Review Report of Mauritius 2019 (for HLPF 2019)
http://foreign.govmu.org/English/Documents/2019/Ministry/vnr/Final%20VNR/VNR%20Draft%20-04.06.19.pdf

Rodrigues Regional Assembly Website:
http://assembly.rra.govmu.org/English/Pages/Intro/The-Parliament.aspx

Alliance for rural electrification (website):
https://www.ruralelec.org/project-case-studies/mascara-renewable-water-solar-powered-seawater-desalination-mauritius

Information on solar powered water desalination technologies:
https://mascara-nt.fr/project/osmosunsw80-ile-de-rodrigues-maurice/

Photos by Maxime Therrillon (m.therrillion@mascara-nt.fr)

Case study 18: Hydropower for CO_2-free Electric Buses in Old Town of Regensburg, Germany

Photos by Ralph Wahnschafft

Organization, Institution or Company
Regensburg Public Transport (Regensburger Verkehrsverbund - RVV) and Regensburg Energy Agency (REWAG) Public Companies of City of Regensburg, Germany
Location of Project Site, Country
Regensburg, Bavaria, Germany

Brief Narrative Objective/Description of Project/Activity/Initiative

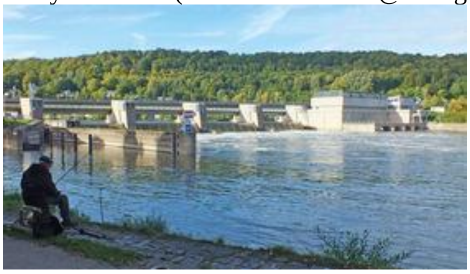
Electric mobility provides options for mitigating local air pollution and carbon emissions if electric vehicle batteries are charged with electricity from renewable sources.

The old town of Regensburg located on the River Danube in South-Eastern Germany was recognized by UNESCO as a World Heritage Site. In order to enhance local living conditions for residents and in order to make the old town attractive for shoppers from surrounding towns and villages and for visiting domestic and international tourists the City of Regensburg and its Public Transport Company have procured 5 new electric city buses which service the old town inner city route and pedestrianized areas around the main historic attractions without noise or motor fuel emissions. The bus batteries are recharged during nights and during the day at a fast-recharge station. The electricity for the city e-bus service is procured exclusively from a near-by run-of-river hydropower station.

Inner City Route “A” is serviced by 5 electric buses manufactured by Rampini Company in Italy. Because many roads in the old town are rather narrow, the busses are small, only 7 meters in length, and 2.2 meters in width. The buses provide seats for 14 passengers, and can carry up to 25 additional passengers standing for the short distance trips. The buses can transport wheelchairs and accessible for elderly people and people with disabilities.

Economic, Environmental and Climate Benefits/Challenges/Lessons Learned

Photo by REWAG (Martin.Gottschalk@rewag.de)



The Run-of-river hydropower station on the River Danube in Pfaffenstein near Regensburg is owned by Rhein-Main-Donau AG and operated by Uniper Kraftwerk GmbH. The hydropower facility was first build in 1977, and renovated in recent years. The facility has a head of 3.8 meters. Power is produced by two turbines with a combined capacity of 7.2 MW. The station produces about 40 Million kWh of CO_2-free electricity for the City of Regensburg, which is sufficient to power some 11,000 homes. Regenburg's electric bus service is powered exclusively by local hydropower, demonstrating an example of a sustainable water-energy-transport solution.

Additional Information: Website Addresses and Contacts

Regenburger Verkehrsverbund (Public Transport Company): https://www.rvv.de/?lang=en

Regensburg Energy Agency (REWAG) http://www.energieagentur-regensburg.de/
(in German only)

Photos by Ralph Wahnschafft

Case study 19: Purification of rural drinking water supply based on renewable energy. Demonstration project of Massachusetts Institute of Technology in La Mancalona, Calamul Campeche, Yucatan, Mexico

Photos by Leah Kelley / MIT News

Organization, Institution or Company
Prototype and demonstration project of Massachusetts Institute of Technology (MIT) in Calamul Campeche Municipality, Mexico, with funding support by W.K. Kellogg Foundation
Location of Project Site, Country
Unión Veinte de Junio / La Mancalona village, Calamul Campeche, Yucatan, Mexico

Brief Narrative Objective/Description of Project/Activity/Initiative

Access to clean and affordable drinking water is a great challenge in many rural areas of developing countries. In Unión Veinte de Junio, also known as La Mancalona, a small rural village with 450 inhabitants on the Yucatan peninsula in Mexico, researchers of the Massachusetts Institute of Technology (MIT), with financial support of the W.K. Kellogg Foundation, have helped to set up a 1,000 liters per day prototype solar photovoltaic-powered reverse osmosis (PVRO) water purification station.

The system uses solar panels to charge batteries, which then power pumps that push brackish well water and collected rainwater through filtration membranes. The batteries also supply the ultra violet sterilization bulbs with electricity.

All parts used in the system can be obtained commercially within Mexico, and the technology and the project concept can easily be replicated in other rural locations.

Economic, Environmental and Climate Benefits/Challenges/Lessons Learned

Villagers have been trained to operate and maintain the PVRO system, which has greatly improved their lives. The water purification station has created a viable business opportunity for the village.

The locally produced clean water is sold for 5 pesos per 20-liter bottle, which is 1/10th of the cost of bottled water that would otherwise need to be bought from another village about an hour away. During its first year of operation the water purification systems earned the community revenues of 49,000 pesos, or US$3,600 equivalent, which fully cover maintenance cost, and leaves some savings to meet urgent village community needs. Similar systems are being installed in two more villages in the province.

The MIT pilot and demonstration project has shown how renewable energy can be used in decentralized and even in remote location to purify local water for human consumption. The project is expected to make a significant positive contribution not only to the health of the population, but also to the local economy in the concerned villages.

Additional information on the project is available to facilitate replication of the technology and business model in other developing country locations, where local water resources are scarce or contaminated.

Additional Information: Website Addresses and Contacts

Sources: Massachusetts Institute of Technology (MIT), MIT News, 2015
http://news.mit.edu/2015/mexican-village-solar-power-purify-water-1008
MIT Video Clip: https://www.youtube.com/watch?v=Rx7iBw086u8

Elasaad, H., et.al. (2015): Field evaluation of a community scale solar powered water purification technology: A case study of a remote Mexican community application, in: Desalination (Elsevier), Vol 375, November 2015, Pages 71- 80.

Mexico News Network
http://www.mexiconewsnetwork.com/en/news/adventure/solar-power-purify-water-mexico/

Case study 20: Ocean current power generation: Example Orbital O2, UK

Organization, Institution or Company

Orbital Marine Power Ltd (formerly Scotrenewable Tidal Ltd) and EMEC European Marine Energy Center, Orkney

Location of Project Site, Country

Orkney Island, Scotland, UK

Brief Narrative Description of Objective/Project/Activity/Initiative

The world's oceans offer great potential resources for renewable and sustainable tidal, ocean current, and ocean thermal energy. However, harnessing these ocean energy resources continues to pose considerable technical challenges. Many demonstration projects have been implemented over the years, but due to high costs and risks only some of the tidal energy projects have been realized. Some of the established projects in this category include the Rance Tidal Power Station in France, the Shiwa Lake Tidal Power Station in Republic of Korea, the JiangXia Tidal Power Station in China, The Swansea Tidal Bay Lagoon in Wales, and the MayGen Tidal Stream Project in Scotland.

In terms of harnessing ocean current the Scotrenewables Tidal Power Ltd has distinguished itself in recent years by designing and constructing a number of floating devices with attached turbines harvesting energy of ocean currents in near Northern European shorelines. In 2012 the company achieved a world first success when it exported power to the UK grid from its 250kW floating scale model, the SR250, at a grid-connected tidal test site of the European Marine Energy Center. The 250kW device measured 33 m, was constructed at Harland & Wolff in Belfast in 2010 and weighed 100 tonnes.

Building on the success of SR250, the company developed the SR2000, a larger 63 m, 500 tonne, 2 MW turbine potentially suited for a tidal array deployment. The SR2000 was first deployed at EMEC's tidal test site in October 2016. It reportedly produced 116 MWh or around 7 per cent of Orkney's electricity demand during its first week and generated 1 GWH in record time since being deployed.

Economic, Environmental and Climate Benefits, Challenges and Lessons Learned

In October 2018, Scotreneables Tidal Power Co. Ltd was re-branded and re-named Orbital Marine Power Ltd, with its new name inspired by the orbital cycle of the moon around the earth, the reliable provider of tidal energy.

The SR1-2000 was removed from site in September 2018 to be replaced by a larger and further optimised 2MW floating tidal turbine, the Orbital O2, to be fully operational at the EMEC site in 2020. The Orbital O2 turbine has a 73m-long floating superstructure, supporting two 1 MW turbines on either side. The turbine has an optimised superstructure design, 50 per cent greater energy capture through increased rotors, lower fabrication cost, better maintenance strategies, and compatibility with the local supply chain and infrastructure. Progress in the deployment of the O2 as the world's largest floating ocean current turbine is promising. The position of the turbine can change with the currents, and its capacity will be equivalent to powering 1,700 homes.

The Orbital O2 project is supported by the Scottish Government (£ 3.4 million) and the European Commission (€ 7 million). Orbital is leading an industrial consortium comprising of the most experienced and committed commercial, industrial and research organisations involved in tidal energy today: DP Energy; Harland and Wolff Heavy Industries; the European Marine Energy Centre (EMEC); ABB Ltd; Eire Composites; Technology from Ideas; University College Cork; EDF Energy and SKF. If the O2 project produces good results and proves successful, ocean current technology may find applications in various parts of the world, in particular in the upper Northern and in the lower Southern where stronger ocean currents are more frequent.

Additional Information: Website Addresses and Contacts

Website of Orbital Marine Company Ltd: https://orbitalmarine.com/

Website of European Commission: www.flotectidal.eu

Photos by Orbital Marine Co.

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