Climate Toolkits

For Infrastructure PPPs

Water Production & treatment Sector

WORLD BANK GROUP
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PPIAF Enabling Infrastructure Investment

Global Infrastructure Facility
A G20 INITIATIVE

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About PPIAF

PPIAF helps developing-country governments strengthen policy, regulations, and institutions that enable sustainable infrastructure with private-sector participation. As part of these efforts, PPIAF promotes knowledge transfer by capturing lessons while funding research and tools; builds capacity to scale infrastructure delivery; and assists sub-national entities in accessing financing without sovereign guarantees. Donor-supported and housed within the World Bank, PPIAF's work helps generate hundreds of millions of dollars in infrastructure investment. While many initiatives focus on structuring and financing infrastructure projects with private participation, PPIAF sets the stage to make this possible.

About the GIF

The Global Infrastructure Facility, a G20 initiative, has the overarching goals of increasing private investment in sustainable infrastructure across emerging markets and developing economies, and improving services that contribute to poverty reduction and equitable growth aligned with the Sustainable Development Goals (SDGs). The GIF provides funding and hands-on technical support to client governments and multilateral development bank partners to build pipelines of bankable sustainable infrastructure. The GIF enables collective action among a wide range of partners—including donors, development finance institutions, and country governments, together with inputs of private sector investors and financiers—to leverage both resources and knowledge to find solutions to sustainable infrastructure financing challenges.

About CTA

IFC's PPP Transaction Advisory (CTA) advises governments on designing and implementing public-private partnership (PPP) projects that provide or expand much needed access to and/or improved delivery of high-quality infrastructure services—such as power, transportation, health, water and sanitation—to people while being affordable for governments. In doing so, CTA assists on the technical, financial, contractual, and procurement aspects of PPP transactions. To date, CTA has signed over 400 projects in 87 countries, mobilizing over $30 billion of private investment in infrastructure, and demonstrating that well-structured PPPs can produce significant development gains even in challenging environments.

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List of Abbreviations and Acronyms

AI	artificial intelligence
AICC	average incremental carbon cost
BEP	best efficiency point
BOT	build-operate-transfer
CAPEX	capital expenditures
CARL	Current Annual Real Losses
CBA	cost-benefit analysis
CCKP	Climate Change Knowledge Portal
CHP	combined heat and power
CMIP	Coupled Model Intercomparison Project
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CTIP3	Climate Toolkits for Infrastructure PPPs
ECAM	energy performance and carbon emissions assessment and monitoring
EIRR	economic internal rate of return
EMDE	emerging market and developing economy
ERD	energy recovery device
EU	European Union
GCM	general circulation models
GESI	Gender Equality and Social Inclusion
GHG	greenhouse gas
GPP	green public procurement
HVAC	heating, ventilation, and air conditioning
IFC	International Finance Corporation
ILI	Infrastructure Leakage Index
IoT	internet of things
IPCC	Intergovernmental Panel on Climate Change
IPCC AR6	Sixth Assessment Report of the Intergovernmental Panel on Climate Change
IPCC WGI	International Panel on Climate Change Working Group I
KPI	key performance indicator
kWh	kilowatt-hour
LTS	long-term strategies
LULC	land use/land cover
MDB	multilateral development bank
MIGA	Multilateral Investment Guarantee Agency
Ml	mega-liters
NAP	national adaptation plan
NAPA	national adaptation program of action

NbS	nature-based solutions
NDCs	Nationally Determined Contributions
NPV	net present value
O&M	operation and maintenance
OPEX	operational expenses
p.e.	population equivalent
PPP	public-private partnership
RCP	Representative Concentration Pathway
SABESP	Saneamento Básico do Estado de São Paulo
SCADA	supervisory control and data acquisition
SDGs	Sustainable Development Goals
SMART	specific, measurable, achievable, relevant, and time-bound
SPP	sustainable public procurement
SSP	Shared Socioeconomic Pathways
TCR	The Climate Registry
TOR	term of reference
UARL	Unavoidable Annual Real Losses
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UN-Water	United Nations Water
USAID	United States Agency for International Development
USGS	United States Geological Survey
VFD	variable frequency drives
VfM	value for money
VSDs	variable speed drivers
WaCCliM	Water and Wastewater Companies for Climate Mitigation
WBCSD	World Business Council for Sustainable Development
WBG	World Bank Group
WEG	water-energy greenhouse gas
WESR	World Environment Situation Room
WRI	World Resources Institute

Foreword

The time for action to build a better future and green recovery has never been stronger as we navigate the uncertainty of a world dealing with multiple crisis on top of climate change. As governments across the globe face fiscal constraints, it has become imperative to crowd in private sector solutions, innovation, and finance to create new solutions and pathways to meet Paris Agreement goals on climate change and UN Sustainable Development Goal (SDG) commitments.

Participation of the private sector in Paris-Aligned infrastructure investments is critical and public-private partnerships (PPPs) are among the key solutions. PPPs are critical in supporting governments to bridge the infrastructure gap not only for the additional capital they bring but sector expertise and innovation as well. However, the PPP model is not without challenges, climate change creates uncertainty that can be difficult to account for in the framework of PPPs, which require a certain degree of predictability to attract investment and finance.

This sector-specific toolkit on the water production and treatment sector aims to address this challenge by embedding a climate approach into upstream PPP structuring. If structured correctly, PPPs in water production and treatment sector can increase climate resilience offering market-based solutions to address both mitigation and adaptation challenges. PPPs are able to provide well-informed and well-balanced risk allocation between partners- offering long-term visibility and stability for the duration of a contract (typically 20 to 30 years)- compensating climate change uncertainty through contractual predictability.

The toolkit attempts to address questions like:

- In what ways-in terms of likelihood and impact-does climate change affect water production and treatment infrastructure projects, and what measures can be taken to alleviate these impacts through a PPP structure? What innovative and cost-effective approaches like nature-based solutions and others can be considered?
- How can we innovate to allow for optimal risk allocation and contractual predictability in an environment marked by uncertainty and the need for resilience to unpredictable scenarios?

The Global Infrastructure Facility (GIF), The Public Private Infrastructure Advisory Facility (PPIAF) and International Finance Corporation, Transaction Advisory, Public-Private Partnership and Corporate Finance Advisory Services in collaboration with sector specialists across the World Bank Group (WBG)-have joined forces to build upon best practice on a topic at the cross-roads of climate change, infrastructure, and private sector participation. It is a field in evolution where there will be a great deal of innovation ahead of us.

Currently an insufficient focus is given to considering climate change in the framework of PPPs. For instance, the PPP tender selection criteria are currently ultimately based on the least cost approach, which may promote assets not resilient enough to withstand climate impacts. This may in turn result in total asset loss with devastating effects on the economy and society. This toolkit is indeed about providing solutions to public officials and their advisors on how to better align interests and incentives towards climate-smart investments and tap into private sector financing capacity.

The water production and treatment sector toolkit as part of the Climate Toolkits for Infrastructure PPPs (CTIP3) suite is ultimately a call for action for decision makers, to push for bold initiatives so that infrastructure investments become a critical and steady pathway to achieve Paris Agreement and SDG commitments.

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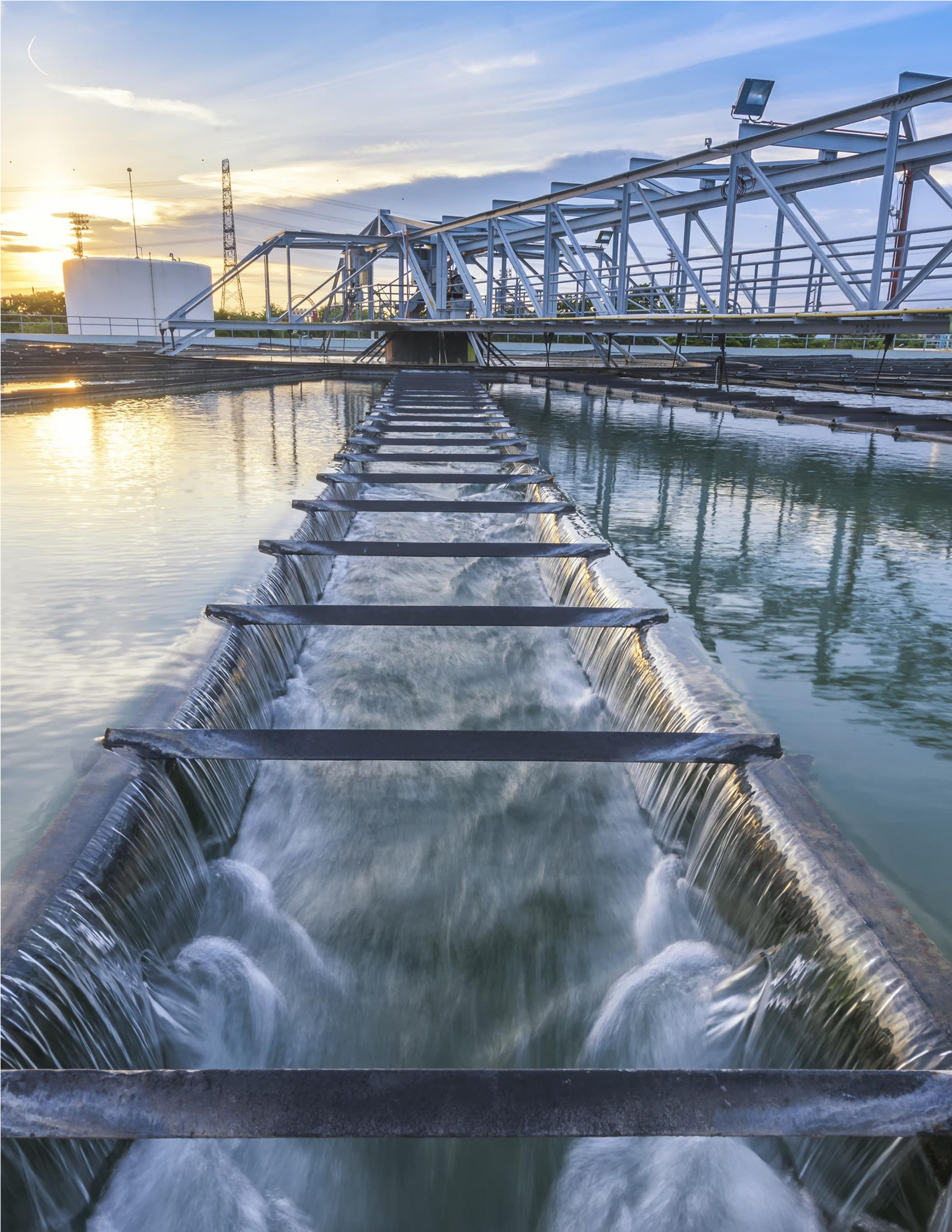


INTRODUCTION

An opportunity to address a global imperative

When compared with that of other infrastructure sectors, private financing of water production and treatment infrastructure—or bulk water supply infrastructure—is limited due to the special challenges involved.[1] However, recent experiences in Africa[2] have demonstrated that public-private partnerships (PPPs) can viably provide reliable, clean water supplies to emerging market and developing economy (EMDE) countries, where hundreds of millions of people are still deprived of access to clean water.

PPPs, when properly designed and structured, can effectively combine the skills and resources of the public and private sectors to create high impact water projects that deliver externalities such as, but not limited to, better health, job creation, and equity and inclusivity. This becomes particularly important in an era when lack of easy access to water places an oversized burden on women and girls, who are often tasked with the tough and time-consuming job of collecting fresh water from wells and boreholes, distracting them from study or other work. Of note, in poor countries in Sub-Saharan Africa, where women tend to be responsible for water collection, they also often bear the financial burden when prices rise in response to drought—so it is not only an issue of access but also of cost.

Climate change: a multi-faceted challenge for the water sector

Climate change is primarily a water crisis. Extreme temperatures intensify water scarcity, and changing precipitation creates uncertainty regarding the availability of surface and groundwater, while flooding and rising sea levels contaminate water resources with saltwater and run-off waste. All these together are making water more scarce, more unpredictable, and more polluted, prohibiting access to safely managed drinking water for billions of people around the world.[3] At the same time, the global population is growing fast (global water demands will increase by 55 percent by 2050), placing unprecedented pressure on the already reduced water resources—the availability of which is expected to decrease by 40 percent during the same period.

New standards in water PPPs

The globally increasing awareness regarding climate change has created a new stream of considerations for PPP procurement. In order to commit to the Paris Agreement's low-carbon pathway, water projects will have to increase capital investments to meet climate mitigation and energy-efficiency targets, and enhance their resilience to the increasing climate threats. Yet, if this is done without fully acknowledging the true savings and financial opportunities, there is a risk of procuring very expensive projects that do not create value for

[1] The primary barrier is the public's fear of potential exploitation of water resources by the private sector. But also private investors consider water concessions, particularly in emerging marking and developing economy (EMDE) countries, to be risky endeavors due to the lack of competition, the high uncertainty of revenue streams, and the low tariffs.

[2] IFC (International Finance Corporation). 2022. "Benefits Flow from Public-Private Water Partnerships (ifc.org)."

[3] UN Water. 2022. "Water and Climate Change." https://www.unwater.org/water-facts/water-and-climate-change.

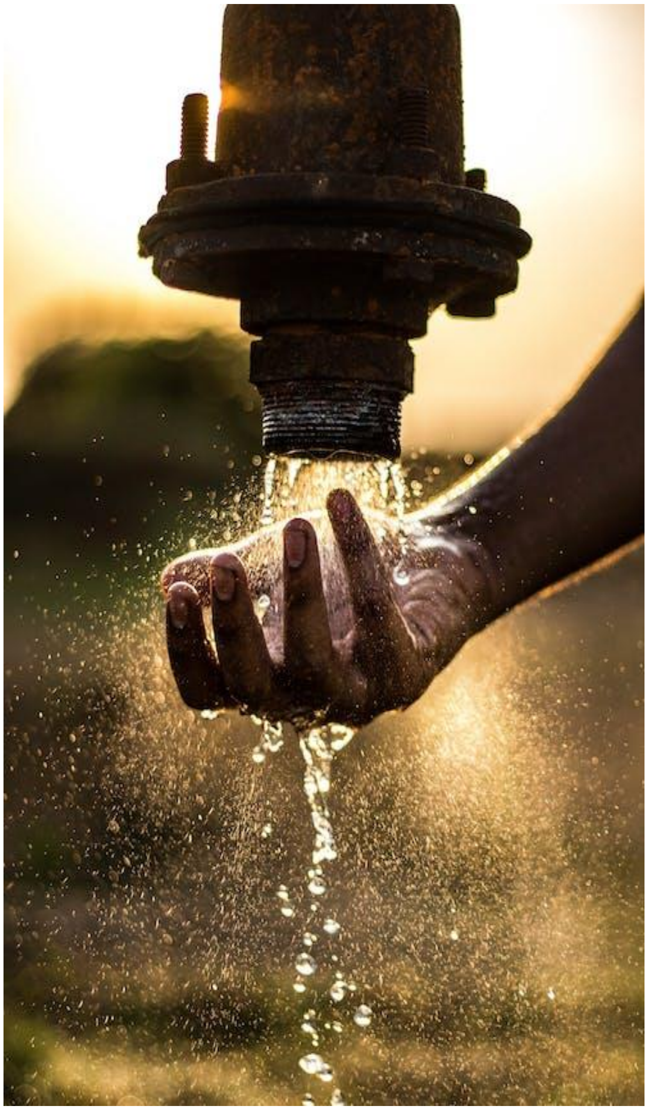
money (VfM) and that are overall prohibitive for private investors.

Furthermore, empirical evidence shows that greater energy efficiencies can be achieved through PPP procurement schemes, provided that proper contracts have been established incentivizing the private sector to improve operational efficiency and service quality. Hence, the way forward is fostering climate mitigation and adaptation in water projects while improving wider sustainability and quality-of-life objectives. In doing so, PPPs can be catalytic in mobilizing innovation and competition while leveraging financing opportunities.

The toolkit and its intended users

This document is intended for use by EMDE government agencies in order to assist them in incorporating climate-related risks and opportunities in the pre-structuring phase of water supply infrastructure projects procured through PPPs. The toolkit complements the World Bank Group's Climate Toolkits for Infrastructure PPPs (CTIP3)[4] (the "Umbrella Toolkit") by providing step-by-step instructions on how to apply its provisions to PPPs related to water supply infrastructure.

The toolkit is intended to familiarize non-experts with the potential effects of climate change on bulk water infrastructure PPP investments—and the resulting considerations for climate mitigation, adaptation, and resilience—so that these can be adequately appraised as early as possible when pursuing such projects. As such, the toolkit focuses on preliminary steps aiming to help users understand how climate change could affect their bulk water infrastructure project, the potential consequences, and what measures can be taken to alleviate impacts. Note that this toolkit is not intended for the design to structuring and tendering phases, but should be consulted as a complementary tool to the Umbrella Toolkit.



[4] World Bank, IFC (International Finance Corporation), and MIGA (Multilateral Investment Guarantee Agency). 2022. Climate Toolkits for Infrastructure PPPs. World Bank, Washington, DC. Referred to as the Umbrella Toolkit in this document.

Typologies and definitions of water production and treatment projects covered by this guide

Definitions

Water production and treatment—or "bulk water"—is a subsector of water and sanitation infrastructure. It includes the production, storage and transmission of treated or untreated water in large quantities for any purpose (e.g., drinking, domestic use, agriculture, industrial use).

A water production and treatment system may include the following phases:

- **Water abstraction:** the process of extracting water from a natural source (i.e., river, lake, or groundwater aquifer) through an intake structure. The intake can either be submerged or exposed, wet or dry.

- **Water conveyance**: the transportation of water from the source to the treatment plant or reservoir. In general, a water conveyance system comprises (i) conduits that can either be open channel flow (i.e., canals, aqueducts, tunnels) or under pressure (i.e., pipes, pressure tunnels, pressure aqueducts), and (ii) reservoirs (i.e., open-air storage area), such as recharge basins, dams across rivers, off-channel reservoirs, or storage tanks.

- **Water treatment**: the alteration of a water source in order to achieve a quality that is safe for consumption, involving the removal of contaminants and/or inactivation of any potentially harmful microbes. The treatment may include one or more of the following processes: (i) coagulation and flocculation (i.e., the addition of compounds that promote the clumping of fine floc into larger floc so that they can be more easily separated from the water); (ii) sedimentation (i.e., the process that removes solids that float and settle in the water); (iii) filtration (i.e., the process of removing or reducing the concentration of particulate matter, including suspended particles, parasites, bacteria, algae, viruses, and fungi, as well as other undesirable chemical and biological contaminants, to produce safe and clean water); (iv) disinfection (i.e., the process of adding chemical disinfectants, such as chlorine, chloramine, or chlorine dioxide, to kill any remaining parasites, bacteria, or viruses in drinking water).

A special type of water treatment is **desalination**, the process of removing dissolved salts from seawater (or from brackish waters of inland seas, highly mineralized groundwater, or municipal wastewater). A desalination plant consists of a water pretreatment system (including microfiltration units, pH adjuster, and cartridge filter), a high-pressure pump, the membrane itself, and post-treatment equipment, such as a degasifier or mineral adjustment unit. There are several desalination technologies, such as reverse osmosis, mechanical vapor compression, multi-stage flash, humidification–dehumidification, membrane distillation, and multi-effect desalination.

Examples of relevant PPPs[5] are provided in **Box 0.1.**

BOX 0.1. EXAMPLES OF WATER PRODUCTION AND TREATMENT INFRASTRUCTURE PPP PROJECTS

Notable PPP examples of water supply infrastructure projects include:

- **Bulacan Bulk Water Supply Project (The Philippines[6]):** A 30-year build-operate-transfer (BOT) PPP that includes the construction and operation of various components such as water sources; aqueduct interconnection, intake and lift station for raw water abstraction; water treatment plant complete with support buildings and structures; treated water reservoir, including sludge treatment facility; raw and treated water conveyance facilities complete with necessary appurtenances; facilities for interconnection with the water districts; bridge, culvert, and river crossings; supervisory control and data acquisition (SCADA) system; booster pump stations; security perimeter fencing; inventory of materials and vehicles; and access road and pipe bridge support.

- **Kigali Bulk Water Supply Project (Rwanda[7]):** A 25-year PPP between the Government of Rwanda and Kigali Water Limited that involves the development, design, financing, construction, and operation of a 40,000 cubic meters (m^3) per day bulk water facility, including a water treatment plant, a well field with 38 wells, three pumping stations, pipelines, and three storage reservoirs.

[5] For guidance on PPP models that are common in bulk water supply infrastructure PPPs, users are referred to the definitions set out in the APMG PPP Certification Guide (2016) and the WBG's Public Private Partnership Legal Resource Center including: Management and Operating Contracts; Leases/Affirmage; Concessions/Build Operate Transfer (BOTs)/Design Build Operate (DBOs)/Design Build Finance Operate (DBFOs); and Joint Ventures/Partial Divestiture of Public Assets.
[6] Republic of the Philippines Public-Private Partnership Center website. "Bulacan Bulk Water Supply Project."
[7] African Development Bank Group Data Portal. "Rwanda - Kigali Bulk Water Supply Project."

EXECUTIVE SUMMARY

This toolkit contains a set of tools covering the major climate entry points (identification of risks, incorporation of climate considerations in the project selection, and appraisal of climate effects in the project's economics). Its inputs are preliminary project data as well as readily available climate-related resources and tools produced by the World Bank Group and other international organizations. The outcome should be a project-specific collection of considerations that will need to be further evaluated and quantified in the subsequent phases of project implementation, as well as an improved understanding of the potential needs for advisory services. The toolkit is divided into five modules:

Module 1 explains the ramifications of the Paris Agreement, national adaptation plans, and other international treaties and national policies for the planning of new water production and treatment infrastructure, and helps users understand what is necessary to ensure a project's alignment with such frameworks.

Module 2 presents a methodology for appraising greenhouse gas (GHG) emissions associated with bulk water infrastructure and identifying mitigation solutions. This is done by identifying the various linkages between the water and energy sectors and understanding the potential for energy savings through appropriate interventions.

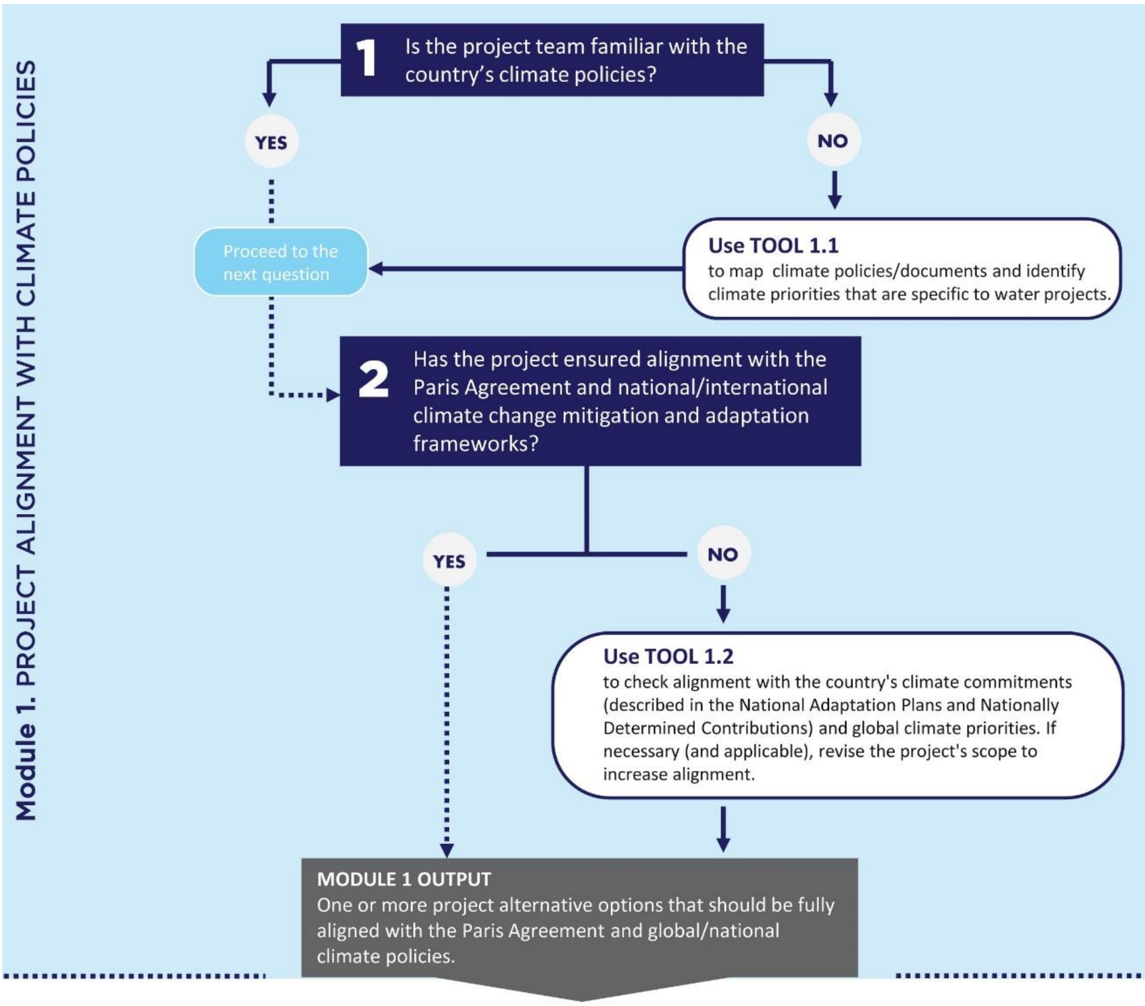
Module 3 proposes a framework for assessing climate risk and managing climate uncertainty in the planning decisions of water projects. This includes understanding the impacts of climate threats on the availability of water resources and the operations of water systems, and setting up adaptation strategies that can perform better given a highly uncertain future.

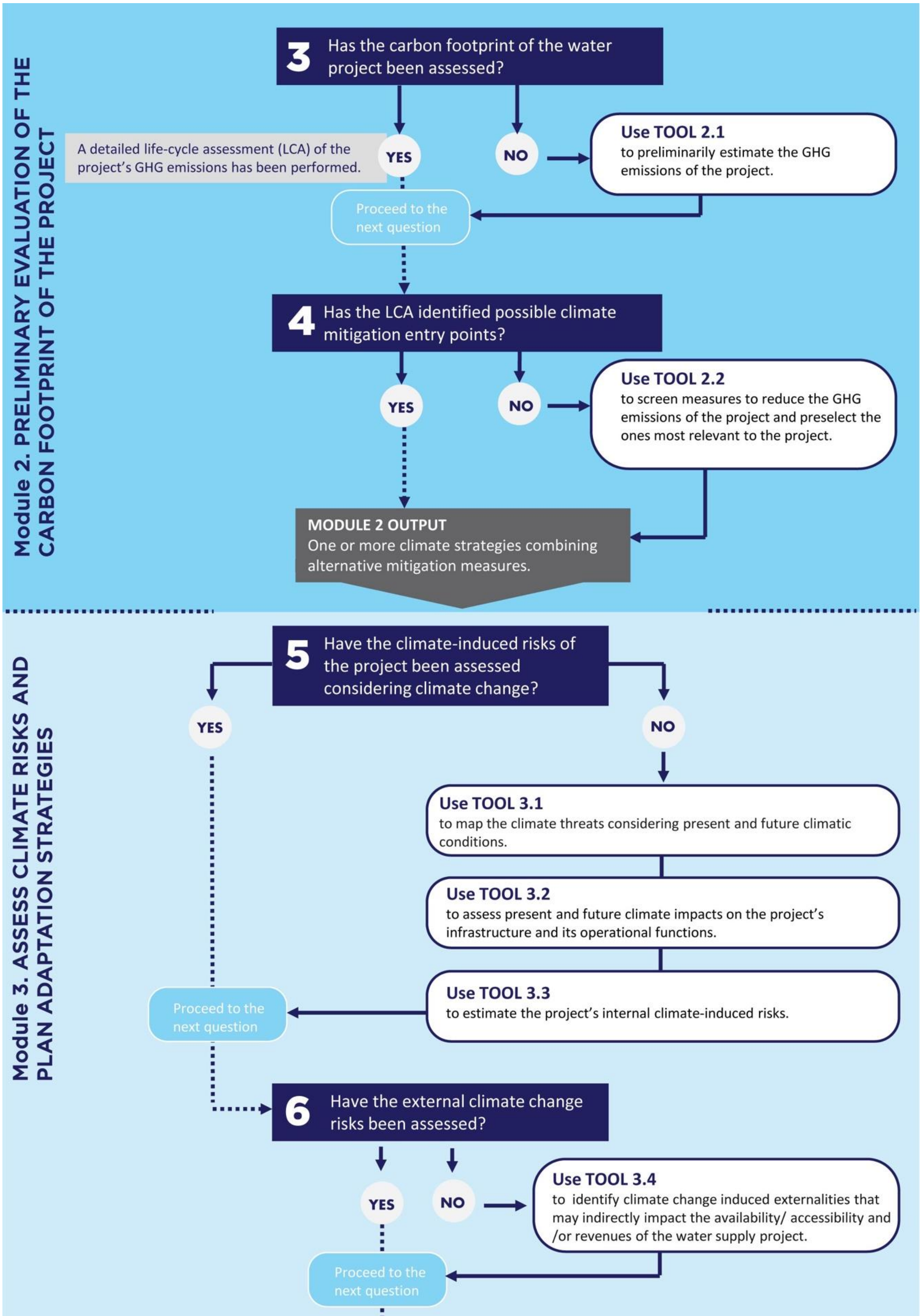
Module 4 guides preliminary economic appraisals of water projects and helps planners recognize how climate considerations may impact the project's cost-benefit analysis (CBA) and its value for money (VfM) as a PPP.

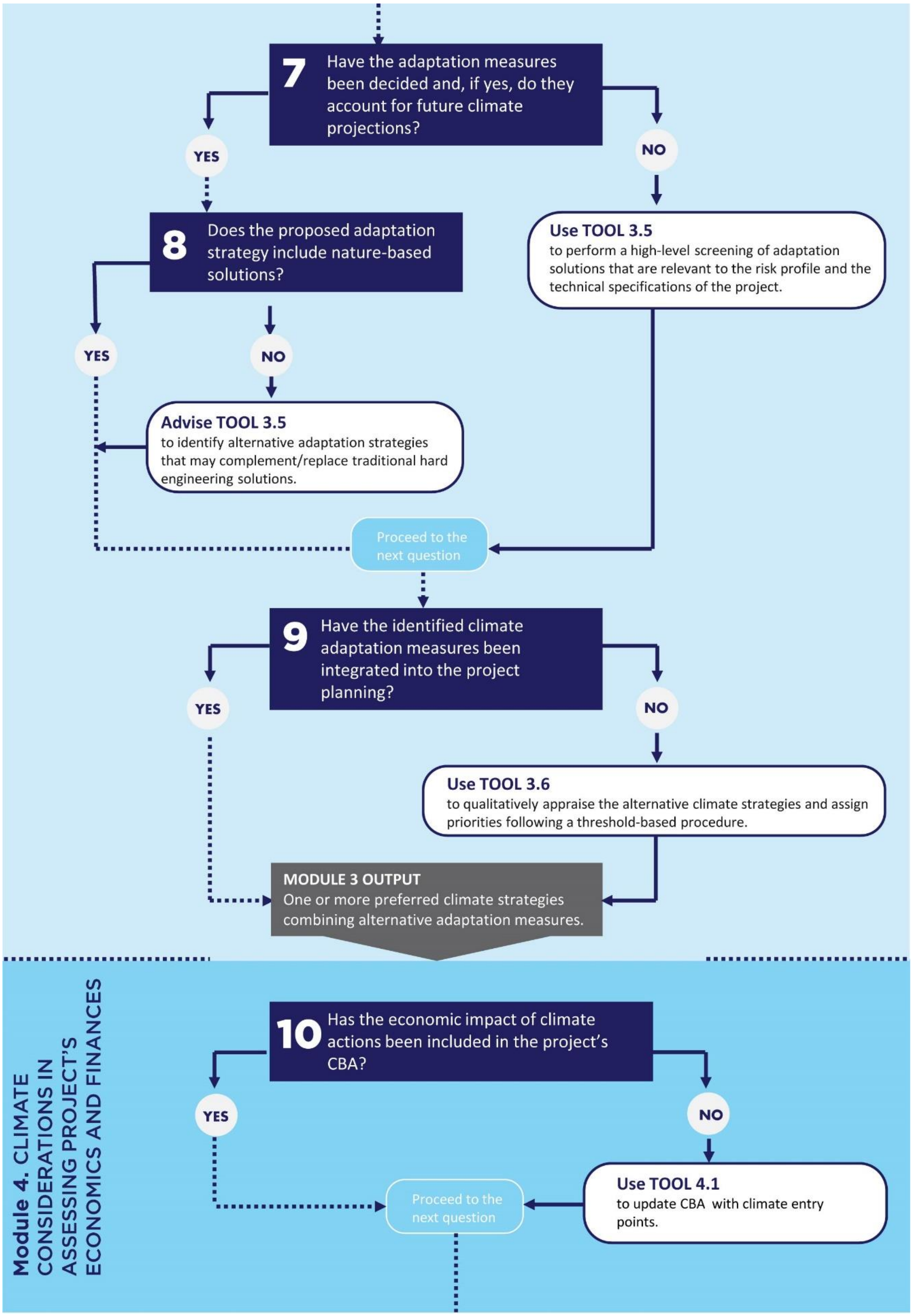
Module 5 proposes a set of output requirements in the form of key performance indicators (KPIs) that can be embedded in the PPP contracts to ensure compliance with the climate objectives and accountability of performance.

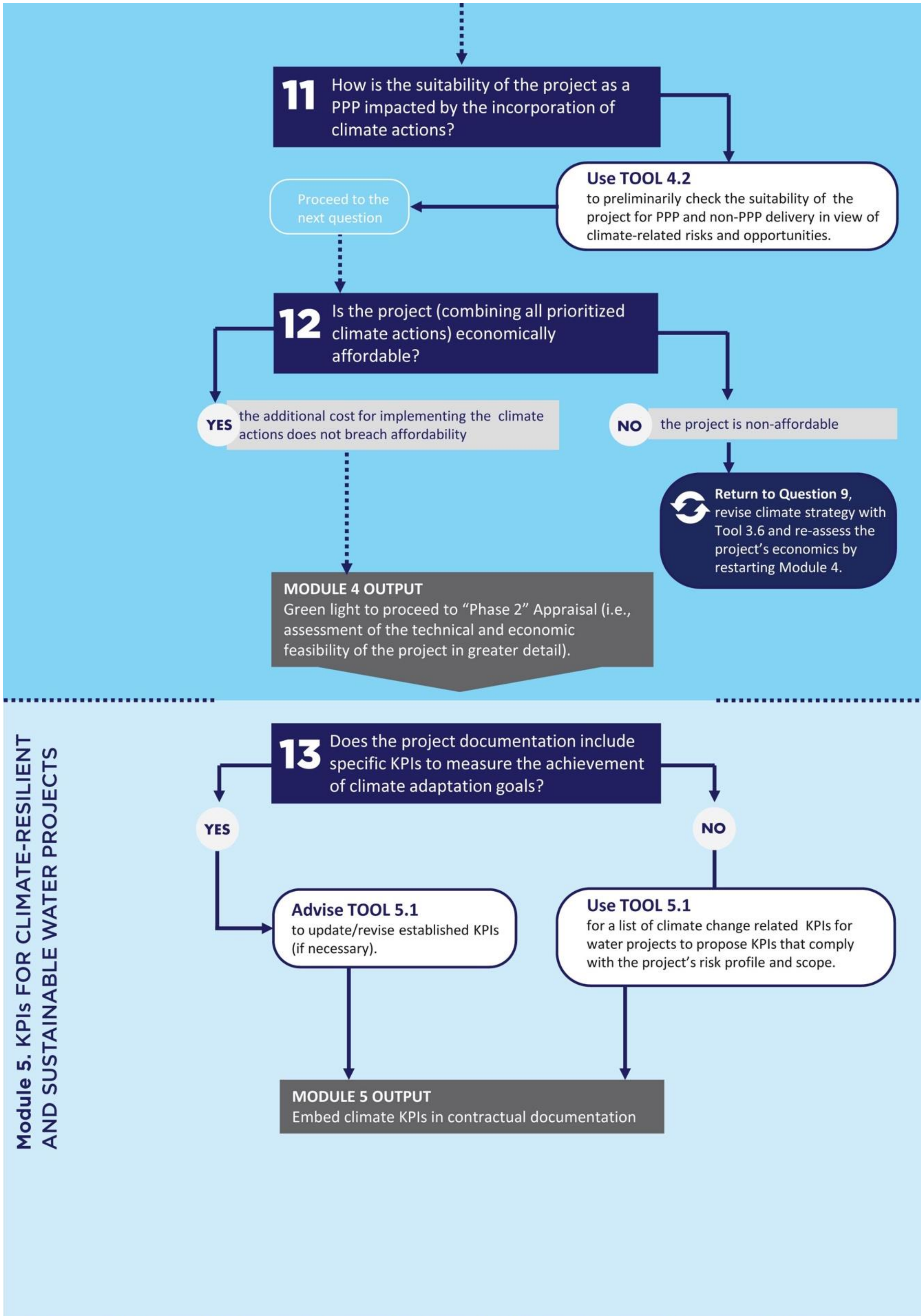
The interconnections between the modules and the tools contained within each module are explained schematically in the **Toolkit Navigator** provided on the next page.

Toolkit Navigator




Module 2. PRELIMINARY EVALUATION OF THE CARBON FOOTPRINT OF THE PROJECT
3 Has the carbon footprint of the water project been assessed?
A detailed life-cycle assessment (LCA) of the project's GHG emissions has been performed.
YES
NO
Use TOOL 2.1
to preliminarily estimate the GHG emissions of the project.
Proceed to the next question
4 Has the LCA identified possible climate mitigation entry points?
YES
NO
Use TOOL 2.2
to screen measures to reduce the GHG emissions of the project and preselect the ones most relevant to the project.
MODULE 2 OUTPUT
One or more climate strategies combining alternative mitigation measures.
Module 3. ASSESS CLIMATE RISKS AND PLAN ADAPTATION STRATEGIES
5 Have the climate-induced risks of the project been assessed considering climate change?
YES
NO
Use TOOL 3.1
to map the climate threats considering present and future climatic conditions.
Use TOOL 3.2
to assess present and future climate impacts on the project's infrastructure and its operational functions.
Use TOOL 3.3
to estimate the project's internal climate-induced risks.
Proceed to the next question
6 Have the external climate change risks been assessed?
YES
NO
Use TOOL 3.4
to identify climate change induced externalities that may indirectly impact the availability/ accessibility and /or revenues of the water supply project.
Proceed to the next question

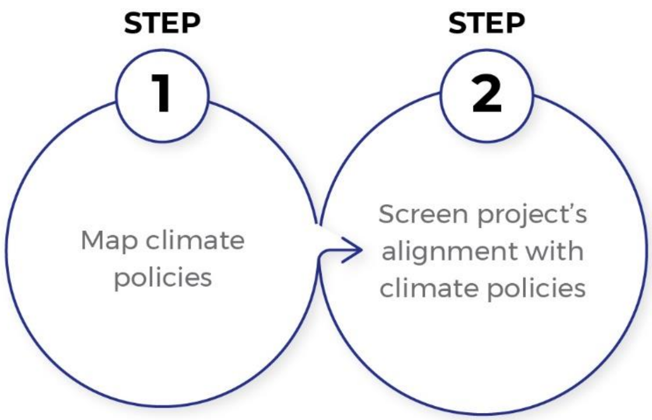

7
Have the adaptation measures been decided and, if yes, do they account for future climate projections?
YES
NO
Use TOOL 3.5
to perform a high-level screening of adaptation solutions that are relevant to the risk profile and the technical specifications of the project.
8
Does the proposed adaptation strategy include nature-based solutions?
YES
NO
Advise TOOL 3.5
to identify alternative adaptation strategies that may complement/replace traditional hard engineering solutions.
Proceed to the next question
9
Have the identified climate adaptation measures been integrated into the project planning?
YES
NO
Use TOOL 3.6
to qualitatively appraise the alternative climate strategies and assign priorities following a threshold-based procedure.
MODULE 3 OUTPUT
One or more preferred climate strategies combining alternative adaptation measures.
Module 4. CLIMATE CONSIDERATIONS IN ASSESSING PROJECT'S ECONOMICS AND FINANCES
10
Has the economic impact of climate actions been included in the project's CBA?
YES
NO
Use TOOL 4.1
to update CBA with climate entry points.
Proceed to the next question


11 How is the suitability of the project as a PPP impacted by the incorporation of climate actions?
Use TOOL 4.2 to preliminarily check the suitability of the project for PPP and non-PPP delivery in view of climate-related risks and opportunities.
Proceed to the next question
12 Is the project (combining all prioritized climate actions) economically affordable?
YES the additional cost for implementing the climate actions does not breach affordability
NO the project is non-affordable
Return to Question 9, revise climate strategy with Tool 3.6 and re-assess the project's economics by restarting Module 4.
MODULE 4 OUTPUT
Green light to proceed to "Phase 2" Appraisal (i.e., assessment of the technical and economic feasibility of the project in greater detail).
Module 5. KPIs FOR CLIMATE-RESILIENT AND SUSTAINABLE WATER PROJECTS
13 Does the project documentation include specific KPIs to measure the achievement of climate adaptation goals?
YES
NO
Advise TOOL 5.1 to update/revise established KPIs (if necessary).
Use TOOL 5.1 for a list of climate change related KPIs for water projects to propose KPIs that comply with the project's risk profile and scope.
MODULE 5 OUTPUT
Embed climate KPIs in contractual documentation

MODULE 1

Module 1

PROJECT ALIGNMENT WITH CLIMATE POLICIES



The water sector presents a huge opportunity to contribute to global adaptation and mitigation goals through the building of climate-resilient and low-carbon water projects. Recognizing this opportunity, the first module of the toolkit provides a methodology to assist users in translating climate ambitions—as expressed through several international and national frameworks—into project-specific climate considerations. The methodology comprises two steps:

Step 1 guides users into mapping climate policies at the national and subnational levels, detailing the specific plans and considerations that are relevant to water supply infrastructure.

Step 2 provides a process for assessing the alignment of the intended project with the country's international commitments as well as national climate-related policies and legal frameworks. This exercise will define the periphery of climate actions that will be detailed and appraised in **Modules 2** and **3**.

Step 1

Map Climate Policies

SCOPE	This step supports the systematic documentation of global and national climate strategies, policies, and plans that set the framework for developing and operating water supply infrastructure. By understanding their underlying principles, targets, and commitments, the relevant agencies will be better prepared and equipped to design and deliver new sustainable water projects that align with the climate mitigation vision of the Paris Agreement and to strengthen the capacity of communities to adapt to the adverse effects of climate change.
PROCESS	The process starts with a quick scan of the country's Nationally Determined Contributions (NDCs), national adaptation plans (NAPs), and long-term strategies (LTS), which are the main national guidance documents for achieving the goals of the Paris Agreement and for identifying climate opportunities for the water supply network. It continues with mapping relevant climate-change references in the country's water supply development strategy and their targets at the national or subnational level. The process concludes with compiling the identified climate elements in these important documents that constitute the national climate policy landscape and the national water-related legislation—whether laws, policy or other official governance documents.
TOOLS	**TOOL 1.1** Mapping climate policies and actors
OUTPUT	A country-specific inventory of the most important policy documents on climate change, with specific references to the delivery of water production and treatment infrastructure and the water supply network.

TOOL 1.1

MAPPING CLIMATE POLICIES AND ACTORS

This tool is designed to facilitate a desk study of the landscape of climate policies and frameworks governing the planning and delivery of water projects based on the mapping methodology presented in the Umbrella Toolkit (Introductory Phase and Module 1.1) while focusing on priorities and provisions that are specific to water supply projects.

For a more in-depth analysis of the country-specific policies and governance mechanisms, agencies are encouraged to seek support within the following agencies:

- The PPP unit (which is expected to have a general mapping exercise for the country's PPP portfolio already completed).
- Relevant ministries (e.g., Ministry of Climate Change, Ministry of Water Development and Sanitation, Ministry of Environment, Ministry of Finance, Ministry of Infrastructure) and their corresponding departments (e.g., Department of Water Supply or Water Management, Department of Water Resources, Water Infrastructure Development).
- Municipalities and other subnational agencies, which are better informed about the climate adaptation activities that happen locally and that may not necessarily be reflected in national policy documents (outlined below).

INPUT

Use this tool to perform a systematic collection and review of climate policy documents. Include in your research as many resources as possible because different resources may highlight different aspects of climate adaptation/mitigation that may be of interest. Use the **Reporting Template 1.1**[8] to report the key findings of this mapping exercise.

1. National documents describing the country's strategic development vision

Focus areas:

- Is the development of new water infrastructure recognized as a strategic vision?
- How does it relate to the Paris Agreement, NDCs, NAPs, the country's Sustainable Development Goals (SDGs) and other applicable policies?
- Is there a national water development plan or policy available? Does it foresee the development of new water systems or the upgrade of existing water supply infrastructure?
- Do the country's strategic development plans envision the involvement of the private sector in its water supply?
- Has the country developed a plan for integrated water resources management?
- Are there any relevant agreements for transboundary developments?
- How is the vision of sustainability supported by new developments in the water sector?
- Are specific water infrastructure assets (e.g., dams) favored as infrastructure systems that can enhance climate adaptation and mitigate water scarcity?

[8] **Reporting Template 1.1** is an indicative template provided only for guidance purposes. The user is free to adopt any other structured format that best suits the project's characteristics and/or the identified policies/documents.

2. **Nationally Determined Contributions** outlining short- and mid-term climate action plans

Focus areas:

- What is the emission reduction target and what are the adaptation goals described in the NDCs?
- What is the contribution of the water sector to the national GHG inventory?
- Do the NDCs identify priorities and GHG emission targets that are specific to the water sector?

3. **Long-term strategy** (if available) outlining the long-term vision of a country on climate change

Focus areas:

- Does the LTS describe a long-term reduction emission goal or a climate change adaptation ambition? What is the horizon?
- Does it specify measures to achieve these goals/ambitions? How do these measures relate to the water supply assets or to the water sector overall? For example, is the need to upgrade the water treatment processes or to divert water supply sources mentioned in the LTS? Is water infrastructure mentioned as a component in the fight against climate change and in adapting to its effects (e.g., through monitoring the GHG emissions produced during operation, raising climate change awareness among the beneficiaries with respect to water scarcity exacerbated by climate change, analyzing short- and long-term climate trends)?
- Do these measures reference social or distributional impact or objectives of climate adaptation and mitigation?

4. **National adaptation plans** (or National Adaptation Programmes of Action or national adaptation strategies) providing a clear framework of how climate-change adaptation actions can be integrated into the development planning of all economy sectors

Focus areas:

- Does the NAP identify water scarcity as a possible future challenge?
- Does the NAP address climate vulnerabilities that are specific to water supply assets? What are the most prominent climate risks identified?
- Does the NAP include an action plan to enhance climate adaptation and resilience? Does the plan recognize opportunities that can be accomplished through new water infrastructure (e.g., an energy-water sector alliance for enhanced climate resilience)?
- Does the approach to NAPs reference processes to ensure integration of diverse stakeholders into the planning process (including gender, broader inclusion)?

Relevant side procedures

The National Adaptation Plan Global Support Programme, implemented by the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP), with funding from the Global Environment Facility and together with the Global Water Partnership, hosted a webinar exchange with more than 60 participants about "Integrating Climate Risks in the Water Sector" with a focus on NAP formulation. The 90-minute webinar *(available here[9]) was an opportunity for countries to share their experiences on integrating water into their NAPs and climate change plans and proposals.[10]*

5. **Climate and environmental legislation** (enforced at either the national or sub-national or state level)

Focus areas:

- Does the legislation specify a "net zero" emissions target? Is this a cross-sectoral target, or does it include specific provisions for the water sector?
- How does the current legislation treat water pollution (limits or standards of effluent discharge into water bodies) and punish non-compliance? Does the climate legislation foresee more stringent measures as a response to climate change?
- Does the legislation describe specific financial vehicles that can help local water facilities to implement energy-efficient strategies (e.g., federal/state funds, energy-performance contracts, lease-purchase agreements)?
- Is there a national disaster risk management policy? Does it prescribe actions to enhance resilience against climate-induced impacts? Are there specific provisions for water assets or targets for accessibility of clean water?
- Which ministries are responsible for the implementation of the law? Is it the responsibility of a single ministry, or are several ministries involved?
- Does the legal framework include provisions for private sector participation as a means to meet environmental sustainability or climate targets?

6. **Water sector strategic development plans or policies** (national or regional)

Focus areas:

- What is described as an environmentally responsible or sustainable water infrastructure?
- What is described as a climate-resilient water supply system?
- What is the strategic role of water infrastructure investment, and how does it address the current and future needs of the users, the communities, and the environment?
- What is the country's vision of water resource management? How does this vision support sustainable growth? Is climate resilience identified as a priority for efficient water resource management?
- Does the strategy include water scarcity considerations, and does it propose or require specific actions to identify, manage and regulate the interconnectedness of environmental threats and water accessibility?
- According to the strategy document, which are the recognized priorities for future water development decisions, and how do they relate directly or indirectly to climate change (e.g., a priority investment to raise rural water supply coverage by ensuring sustainable functionality of the proposed water supply system through effective management structures[11])?

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[9] Global Water Partnership South Africa. "Webinar on Integrating Climate Risks in the Water Sector." https://www.youtube.com/watch?v=cGZP7gPX8kU&t=679s.

[10] UNDP (United Nations Development Programme). 2021. "Integrating water into the National Adaptation Plan process." UNDP news release, October 26, 2021. https://www.adaptation-undp.org/integrating-water-into-the-national-adaptation-plan-process.

[11] Republic of Rwanda Ministry of Infrastructure. 2010. *National Policy & Strategy for Water Supply and Sanitation Services*. https://www.mininfra.gov.rw/index.php?eID=dumpFile&t=f&f=16088&token=02ea412d864526b15ff2d84bfc93d76c36f1da86

- Does the strategy document describe areas of climate action that require a cross-sectoral approach (e.g., a water-energy framework describing the integrated challenge and opportunity space around the water-energy nexus or the agriculture-water nexus)?
- Does the strategy document foresee specific investment plans/financing instruments to enhance water sustainability and resilience, including PPPs?
- Does the strategy document target decarbonization of water infrastructure (e.g., delivering on their own or purchasing more renewable energy, or investing in more efficient equipment)? Does it offer any guidance on decarbonization priorities and objectives in water projects?
  - Does the document set other environmental targets? For example, is there a target to achieve no net loss of biodiversity, to reduce carbon emissions to a specified target level, or to achieve initiatives for leveraging ecosystems and ecosystem services with the help of water infrastructure?
  - Does the strategy include standards, guidelines, or requirements around water management for public and private entities?
  - Does the strategy include criteria or considerations for the distributional or gender impact, or requirements in terms of inclusive processes for policy or plan formulation?
  - Which entities (i.e., ministries) are responsible for implementing the plans?

Example

The Water Sector Strategic Development Plan (2012-2025) of Ghana[12] *lists five key strategies for enhancing water security and climate change resilience: (i) strengthening the regulatory framework for managing and protecting water resources for improved water security and enhanced resilience to climate change; (ii) improving access to knowledge and expertise in integrated water resource management to facilitate water resource planning and decision-making; (iii) improving institutional and human resources capacities for integrated water resources management implementation at all levels; (iv) enhancing public awareness and education in water resource management issues; and (v) enhancing trans-boundary and international cooperation in the management of shared water resources.*

7. **National infrastructure strategy or plan,** outlining long-term goals for key national infrastructure development, with plans and funding commitments to support them

Focus areas:

- Does the strategy recognize key climate-related interdependencies between water infrastructure and other sectors (e.g., energy sector, agriculture)?
- Does it discuss the role that water may play in other infrastructure sectors (i.e., how strong are their dependencies on water use?), and are water-related issues raised in their adaptation and mitigation strategies?
- Does it prescribe a harmonized strategy across the dependent sectors for achieving reduced GHG emissions? Does it mention specific initiatives/action plans (e.g., a water conservation plan would reduce water and energy emissions)?

[12] Republic of Ghana Ministry of Water Resources, Works and Housing. 2014. *Water Sector Strategic Development Plan (2012-2025): Sustainable Water and Basic Sanitation for All by 2025*. http://www.gwcl.com.gh/water_sector_strategic_development__plan.pdf.

8. **Reservoir (water) management plans,** describing how the public land is managed and guiding decisions on land-use requests

Focus areas:

- Does the reservoir management plan outline areas of increased climate risk (e.g., human-induced land subsidence, up-to-date cataloguing of flood plains)?
- Does it describe how climate change may affect the water supply and water quality? What are the main risks identified and what is the plan for addressing them?
- Are there provisions for integrating wetlands in the water management plans (e.g., for flood protection)?

9. **Procurement policies**

Focus areas:

- Does the country have a regulatory framework for PPPs in place?
- Is there a previous track record of bulk water project procurement through PPPs?
- Does the regulatory framework that governs public procurement authorize the voluntary or mandatory application of Green Public Procurement (GPP)[13] practices? Examples include minimum environmental criteria (such as an energy efficiency standard or a share of recycled content) for all or specific procurement categories; a requirement that specific product categories be purchased from a pre-approved product and supplier list that meets the required environmental criteria; a requirement that environmental criteria are considered during the procurement process for specific procurement categories.

Example

The Office of the Controller General of Peru released the Guidelines for Sustainable Public Procurement (SPP), listing 25 legal instruments (laws, decrees, resolutions) that inform SPP implementation in the country. The guidelines set out mandatory minimum criteria for recycled content of paper and plastics, bans on single-use plastic, energy efficiency, certified paper, water-saving equipment, and sustainable construction (WBG 2021).

10. **Development institutions' investment frameworks/strategies and bilateral agreements** with neighboring states/regions

Focus areas:

- Is the project compatible with the goals discussed in the country's investment strategies (e.g., the World Bank Group's Country Partnership Framework (CPF) and Country Climate and Development Reports (CCDRs))?
- Is there an agreement for mutual exploitation of shared water resources?
- Are there existing provisions on transboundary environmental and social impact assessment? Are they based on mutually agreed criteria?
- Is there a water emergency plan? Which conditions qualify as a water emergency?

[13] WBG. 2021. *Green Public Procurement: An Overview of Green Reforms in Country Procurement Systems*. Washington, DC: International Bank for Reconstruction and Development/The World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/36508/Green-Public-Procurement-An-Overview-of-Green-Reforms-in-Country-Procurement-Systems.pdf?sequence=1&isAllowed=y.

Good practices and climate-related guidelines describing opportunities and entry points for integrating green attributes/practices in water projects

- A high-level description of major climate taxonomies and the definition of eligible activities may be found in the Umbrella Toolkit (Insights 1.3 and 1.4).
- Essential resources that are specific to water projects are cataloged in **Module 2** of this toolkit.

OUTPUT

Climate entry points in national (water) policies and strategic plans.

Reporting Template 1.1 Climate entry points in policy documents

Policy Document	Document Type	Coverage	Entity in Charge	Climate Provisions/ Water Sector References
Name (year)	Strategy, law, policy, action plan, or taxonomy	National/ subnational/ regional	Intra-governmental entity (ministries, municipalities)	Summarize key points
Complete as appropriate				

Step 2

Screen Project's Alignment With Climate Policies

SCOPE	This step examines the project's scope vis-à-vis the mapped climate policies and the country's national development goals (outcome of **Tool 1.1**) and qualitatively appraises the project's contribution to these high-level climate priorities and efforts.
PROCESS	The alignment process is performed in two stages that are implemented during different phases of the project preparation: The **preliminary screening** may be performed **immediately after the project inception phase** (when the only available information is the outline of the project scope and the need it addresses). This first-level screening is meant to confirm that the overall project scope aligns with (or at least does not deviate from) the national vision for climate mitigation and adaptation. The **second-level screening** may be performed **towards the end of the project selection and prior to the appraisal of the economic value of the project**. At this stage, the project's risk profile has been qualitatively assessed, and a preliminary discussion on adaptation/mitigation measures is underway. This is the right time to re-evaluate the project's alignment with the national climate agenda (focusing now on specific project attributes) and re-adjust where necessary.
TOOLS	**TOOL 1.2** Screening project's alignment with climate policies
OUTPUT	▪ Climate alignment status (pre-screening and final screen) ▪ Actions to enhance the level of alignment (if deemed necessary)

TOOL 1.2

SCREENING PROJECT'S ALIGNMENT WITH CLIMATE POLICIES

The tool (that is intended to complement the methodology described in the Umbrella Toolkit (Module 1.1)) may be used to qualitatively assess the project's climate profile and its alignment with the vision, goals, and targets described in major climate policies. The tool is structured in the form of a checklist comprising four pillars (**P1** through **P4**):

- Overall alignment of the project's scope with Sustainable Development Goals and the Paris Agreement framework **(P1).**
- Overall alignment of the project's scope with the national climate agenda (primarily described in the NDCs, NAPs, LTS, and other relevant documents) **(P2).**
- Specific interventions contributing to climate mitigation **(P3).**
- Specific interventions contributing to climate adaptation and resilience of the project and of the broader community **(P4).**

INSTRUCTIONS

1. **Define the type of screening.**
   For a **high-level screening** (performed during the very early stages of the project), users may focus on the first two pillars (P1 and P2) only. During the **second-level screening** (implemented towards the end of the project selection), it is recommended to use the entire checklist (P1 to P4).

2. **Use the input module of the tool to screen the performance of the project with respect to each of the four pillars**.

3. **Use the output module of the tool to appraise the alignment status of the project.**

4. **Propose an action plan** to re-align the project scope towards a more sustainable and climate-resilient pathway. The action plan should be targeted to those pillars that have received relatively low scores.

INPUT

The following checklist compiles the criteria contributing to a project's alignment with the national and international climate policies into the relevant pillars (P1 through P4). Users are prompted to qualitatively assess the performance of the project in each of the four pillars considering all the sub-criteria mentioned in the left columns. The goal is to be able to identify areas of poor alignment and seek improvements at an early stage, acknowledging that poor alignment may call into question the project's eligibility for funding by several sources, including multilateral development banks (MDBs). To facilitate the appraisal process, indicative examples of positive review responses and measures to reinforce alignment are provided in the right column.

Four Pillars for Appraising Alignment

P1 ALIGNMENT WITH THE SUSTAINABLE DEVELOPMENT GOALS AND THE PARIS AGREEMENT FRAMEWORK

Sub-criteria	Indicators of alignment/measures to improve alignment (non-exhaustive list of examples)
What is the project's primary purpose, and how does it support the country's Sustainable Development Goals?	**Indicators of effective policy alignment** • Water supply infrastructure contributes directly to **SDG 6**: Clean water and sanitation for all,[14] and additional project-specific contributions may be identified in **SDG 3**: Good health and well-being (e.g., by achieving long-term health benefits through tackling contaminants in the water supply); **SDG 7**: Affordable and clean energy (e.g., in case of on-site renewable energy generation); **SDG 8**: Decent work and economic growth (e.g., by boosting job creation); **SDG 9**: Industry, innovation and infrastructure (e.g., by adopting smart systems for the water supply network and energy monitoring with artificial intelligence systems); **SDG 12**: Responsible consumption and production (e.g., by adopting the circular economy principles and by constant monitoring of water consumption); **SDG 13**: Climate action (e.g., by implementing low carbon measures or replacing hard engineering options with nature-based solutions); **SDG 14**: Life below water (by tackling contaminants and limiting wastewater discharge); **SDG 15**: Life on land (e.g., by responsible management of natural resources).
Does the project support the country's efforts to reduce CO_2 emissions?	**Measures for improved alignment** • Ensure that the project's GHG emissions are estimated thoroughly (considering its entire life cycle), and that they implement energy efficiency and low-carbon measures or use energy generated from renewable sources. • Identify aspects of water projects that cause the greatest GHG emissions and should be proactively examined.
Is climate adaptation an objective of the project?	**Indicators of effective policy alignment** • The project improves the population's access to clean water through reliable and resilient water infrastructure, including the continuous supply of

[14] United Nations Regional Information Centre for Western Europe. "Goal 6: Ensure access to water and sanitation for all." https://unric.org/en/sdg-6/.

Sub-criteria	**Indicators of alignment/measures to improve alignment** (non-exhaustive list of examples)
	water to critical infrastructure (e.g., hospitals) during weather-related catastrophic events. • The project will support sustainable agricultural growth that reinforces the ability of agriculture to adapt to climate change. ▪ The project will include schemes for water conservation (e.g., early leakage detection) in bulk water conveyance infrastructure components. **Measures for improved alignment** • Perform a comprehensive climate risk assessment as part of the feasibility study. • Incorporate changing climate trends into the planning decisions.
Does the project address greater overall inclusion, and gender equality, and does it consider vulnerable groups?	**Indicators of effective policy alignment** • The project can provide an adequate quantity of bulk water for distribution to consumers living in low-income, informal or rural areas (thus contributing toward social cohesion and gender inclusivity[15]). • The project will plan outreach and education to community members about the energy and water efficiency strategies that are being implemented and will include input in formulating policies from diverse stakeholders, including assessing opportunities to enhance benefits in terms of gender and social inclusion. • The project will include an analysis of distributional impacts (i.e., if tariffs will increase) and identification of strategies to mitigate them, including, for example, connection subsidies where feasible, social safety net programs covering water costs for vulnerable households, or social tariffs for low-consuming/low-income households. **Measures for improved alignment** • Ensure that consultations with stakeholders (especially representatives of local communities) are carried out in a respectful and inclusive way throughout the project preparation, incorporating all the different views of beneficiaries, and that they are tailored to the needs of disadvantaged and vulnerable groups. • Develop alternative lower-cost service options through community-based schemes (e.g., water provided in bulk at settlements with high poverty rates) while ensuring that final retail prices will be

[15] The World Bank Group's 2021 document "Green, Resilient and Inclusive Development (GRID)" provides further guidance on gender aspects. https://thedocs.worldbank.org/en/doc/9385bfef1c330ed6ed972dd9e70d0fb7-0200022021/green-resilient-and-inclusive-development-grid.

Sub-criteria	**Indicators of alignment/measures to improve alignment** (non-exhaustive list of examples)
	monitored at shared water points to ensure they are reflective of increased supply. • Integrate a gender and inclusion assessment of the project.

P2 DOES THE PROJECT ALIGN WITH NATIONAL CLIMATE POLICIES?

Sub-criteria	**Indicators of alignment/measures to improve alignment** (non-exhaustive list of examples)
How does the project support the implementation of the country's NDC and the sustainable agenda of the water utilities master plan?	**Indicators of effective policy alignment** • The project supports the use of renewable energy sources for its operational power supply by promoting energy purchases from renewable sources. **Measures for improved alignment** • Consider the degree to which the project satisfies the overall target for decarbonization of the water sector, as determined in the country's NDC, and build an energy management plan to increase compliance with the prescribed targets.
Does the project contribute to the GHG reduction target prescribed in the NDC?	**Indicators of effective policy alignment** • The project will implement green practices to reduce GHG emissions (e.g., optimizing water management resources, re-using wastewater). **Measures for improved alignment** • Use best energy-saving practices and technology innovations that are improving energy savings (e.g., smart metering). • Set a GHG emission reduction target (that complies with NDC efforts) and develop a GHG inventory management plan to track and report progress.
How does the project contribute to climate adaptation efforts outlined in the country's NDCs, NAPs, or other relevant national policies?	**Indicators of effective policy alignment** • The project will reinforce the climate resilience of the water infrastructure (e.g., by identifying and protecting critical components or by frequently updating the drought contingency plans). • The project will prioritize adaptation measures in zones where vulnerabilities are highest and there is a greater need for resilience and safety. **Measures for improved alignment** • Develop a good understanding of the future conditions (i.e., seasonal and permanent variations

Sub-criteria	Indicators of alignment/measures to improve alignment (non-exhaustive list of examples)
	of the water cycle) in which the water facilities will operate. • Set up high-resolution climatic and hydro-meteorological scenarios. • Assess climate risks using multiple plausible futures (being compatible with different general circulation models' projections) to identify the needs for adaptation planning.
Has the country's NDC or NAP diagnosed particular vulnerabilities for water assets? If yes, how is the project intended to address these vulnerabilities?	**Measures for improved alignment**[16] • Ensure that associated risks have been addressed in a thorough manner, considering the inherent uncertainties of the future. • Plan risk mitigation solutions that can efficiently manage climate and non-climate changes (e.g., population growth, intensified agricultural activity).

P3 PROJECT'S POTENTIAL TO REDUCE GHG EMISSIONS. DOES THE PROJECT INCORPORATE SMALL-SCALE MITIGATION?

Sub-criteria	Indicators of alignment/measures to improve alignment (non-exhaustive list of examples)
Will the project include activities to avoid/reduce GHG emissions?	**Indicators of effective policy alignment** • The project is planned to optimize the energy consumption of major equipment/facilities (e.g., use of efficient pumping systems). • The project will integrate water use efficiency approaches to achieve enhanced energy savings (e.g., minimize water leaks, use of recycled water). **Measures for improved alignment** • Obtain adequate information on energy-efficient technologies, their costs and benefits, and available financing schemes, and pursue innovative financing options. • Include in the contractual documents KPIs for measuring/reporting GHG reductions.
Will the project include small-scale climate mitigation components?	**Indicators of effective policy alignment** • The energy needs of the facility will be partially covered by on-site renewable energy generation (e.g., through the installation of photovoltaic panels or small-scale wind turbines).

[16] Although it is important to identify the need for alignment early on in the process, the measures proposed in this particular indicator will only be satisfied later, after the risks have been assessed and the mitigation measures proposed.

Sub-criteria	Indicators of alignment/measures to improve alignment (non-exhaustive list of examples)
	• The project will implement best practices for improving heating, ventilation and air conditioning (HVAC)/lighting efficiency. **Measures for improved alignment** • Include in the contractual documents KPIs for measuring energy consumption.
Will the project adopt nature-based solutions (NbS) for protection against climate risks?	**Indicators of effective policy alignment** • The project will leverage wetlands for water storage and/or protect the water facilities and equipment against flooding, droughts, or other climate risks. **Measures for improved alignment** • Include in the terms of reference (TORs) provisions for the development of coastal restoration plans. The latter should consider the impacts of sea-level rise and development of future ecosystem distribution. • Include in the contractual documents KPIs for measuring habitat loss of coastal landforms and wetlands.
Will the water project include energy-efficiency provisions during manufacture/construction?	**Measures for improved alignment** • Include TOR provisions that promote: - The application of circular economy principles[17] in the design of the water supply system. - Involvement of sustainable-certified suppliers and contractors. - The implementation of energy-efficient practices during construction. • Include in the contractual documents KPIs for measuring/reporting energy savings.
Does the project promote the sustainable use and management of ecosystems?	**Measures for improved alignment** • Design interventions to safeguard watersheds. • Monitor the environmental impact of the project and act in time when deviations from the specified targets are observed.

P4 INCORPORATION OF A SPECIFIC STRATEGY FOR ADAPTING TO CLIMATE CHANGE

[17] Delgado, Anna, Diego J. Rodriguez, Carlo A. Amadei, and Midori Makino. 2021. "Water in Circular Economy and Resilience." Working Paper, World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/36254.

Sub-criteria	Indicators of alignment/measures to improve alignment (non-exhaustive list of examples)
Does the project incorporate methods to reduce the project's exposure/ vulnerability to climatic risks?	**Measures for improved alignment** • Perform detailed risk studies for current and future climate conditions (e.g., water stress analysis, precipitation projections, current and future flood risk maps, geohazard mapping).
How will the project adapt to the adverse impact of climate change?	**Indicators of effective policy alignment** • As part of the feasibility study, a comprehensive climate risk assessment will be conducted. The analysis will couple down-scaled climate projections (for different Representative Concentration Pathways (RCPs)) and hydrological models to predict inflows and outflows covering a range of possible future scenarios. • In cases where there is adequate institutional capacity, adaptation measures may be selected using methodologies that allow for decision-making under uncertainty to account for multiple plausible future climatic scenarios. **Measures for improved alignment** • Design and appraise adaptation strategies for different climate scenarios (e.g., robust water storage systems, flood defense measures). • Leverage opportunities in disaster response and prevention (e.g., through the improvement of contingency planning and the implementation of early warning systems). • Undertake analysis of differential distributional impact by gender and for vulnerable groups, and require actions to mitigate such impacts.
Does the project promote/facilitate the integration of activities that support adaptive management through integrated observation/ monitoring and use of decision-support tools?	**Measures for improved alignment** • Design adaptation measures based on the principles of adaptive/robust planning (e.g., diversify water supply sources in response to changing climatic scenarios).
Does the project enhance climate resilience within the broader ecosystem?	**Measures for improved alignment** • Install weather forecasting systems. • Implement early warning and disaster prediction systems. • Promote awareness among beneficiaries for responsible water use.
Does the project incorporate or support NbS or eco-friendly measures for climate adaptation?	**Measures for improved alignment** • Assess potential environmental impacts and propose contingency NbS or eco-friendly measures by conducting a thorough scoping exercise prior to the construction of permanent interventions.
Will the project include emergency procedures/equipment for climate risks?	**Measures for improved alignment** • Install data-driven technologies and smart information systems (e.g., continuous monitoring and adaptive

Sub-criteria	Indicators of alignment/measures to improve alignment (non-exhaustive list of examples)
	control with smart valves) for disaster risk management during extreme events. • Prepare climate disaster response plans.
Does the project design consider how climate change impacts specifically affect women and vulnerable populations?	**Indicators of effective policy alignment** • The project will use an inclusive, participatory design that mainstreams Gender Equity and Social Inclusion (GESI[18]) measures. • The facility will contribute to subsidies and other support to those in greater need. **Measures for improved alignment** • The feasibility team must have a common understanding of GESI before they start work, and feasibility instruments must be reviewed from a GESI perspective. • Include gendered vulnerabilities in the climate risk analysis. • Ensure adaptation measures are gender-neutral or gender-inclusive.
Does the project mainstream gender concerns in its programs and activities?	**Indicators of effective policy alignment** • Have the project preparation run in parallel with a gender action plan to ensure that women have equal opportunities with men to participate and receive the project benefits (e.g., request that the private party has targets on the promotion of female staff and has in place policies on gender equality). **Measures for improved alignment** • Define sex-disaggregated indicators, outcomes, and/or output level results that will be relevant for proper monitoring to be carried out. • Include TORs that stipulate gender expertise and concrete deliverables during preparation and implementation.

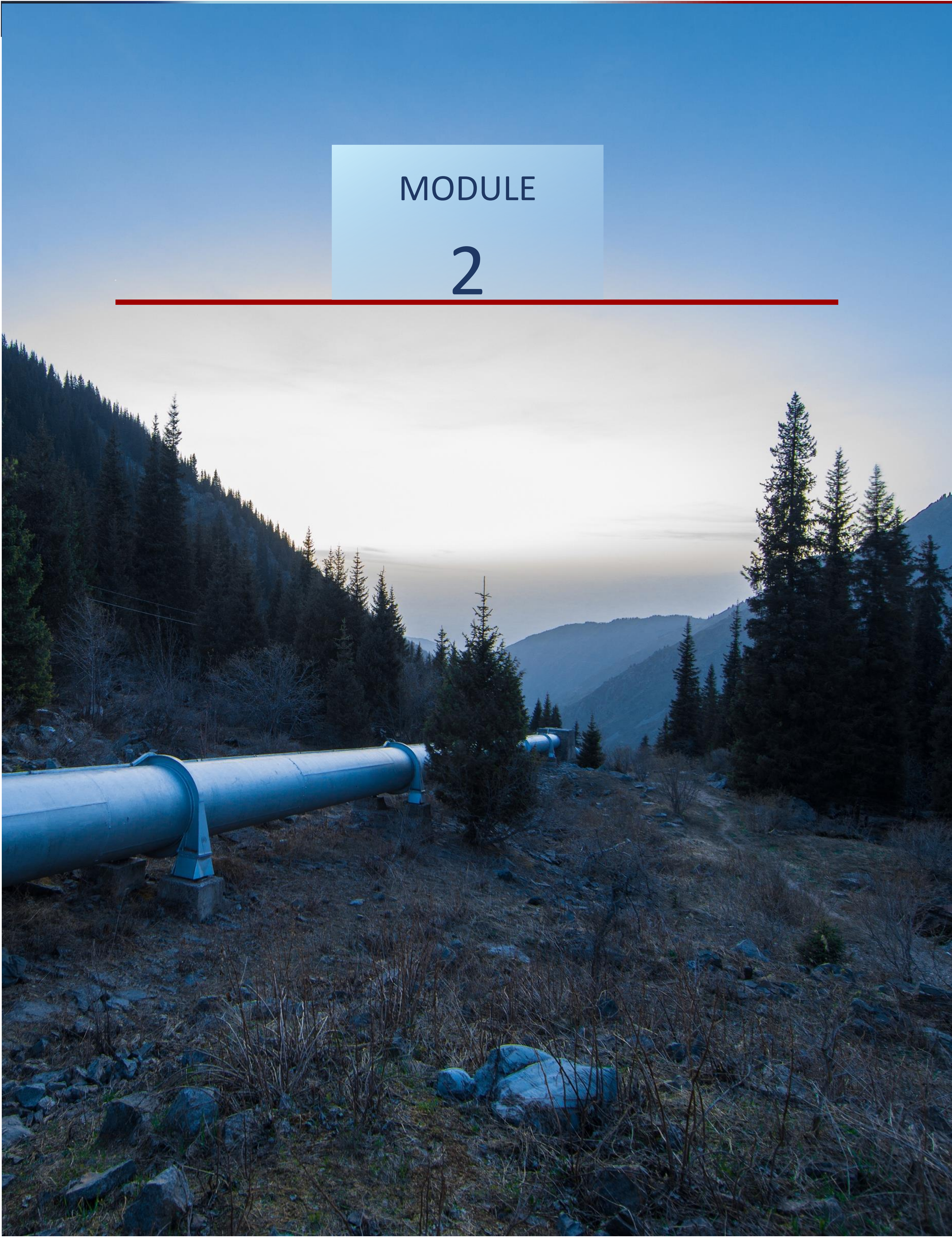
OUTPUT

Following the above process, users are expected to have identified the areas where the project is well aligned with the Paris Agreement goals and the relevant national priorities—as well as the ones where further improvement is necessary. Given that this module is meant to be applied during the very early stages of project planning, some of the alignment indicators will need to be estimated based on preliminary data (that may be subject to changes). Such indicators should be revisited and perhaps re-evaluated during the next phases, after the results of various assessments have been made available. In most cases, it may be practical to initially appraise the indicators of Pillars 1 and 2 and revisit Pillars 3 and 4 after completion of Modules 2 and 3 of this toolkit. For more detailed guidance, users are also encouraged to refer to the description provided in the Umbrella Toolkit (Phase 1).

[18] According to the UN Interagency Rehabilitation Program (2016), GESI is a concept that addresses improving access to livelihood assets and services for ALL, including the women, poor, and excluded.

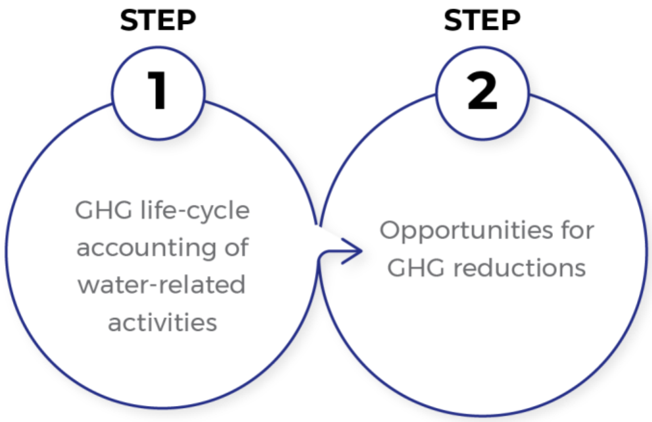
MODULE

2



Module 2

PRELIMINARY EVALUATION OF THE CARBON FOOTPRINT OF THE PROJECT



The second module of the toolkit is devoted to the appraisal of GHG emissions associated with the water project and the opportunities that may exist to mitigate them. GHG emissions are mainly attributable to the energy required to perform activities such as water treatment and pumping. Yet there are several under-recognized opportunities in water projects to further reduce carbon emissions and mitigate climate change. What is more, as water scarcity intensifies (due to climate change and/or as more water supplies are affected by decreasing quantity or quality), while global demand for water increases, it has become more important to understand the water sector's energy requirements and to take measures that will promote sustainable water management and energy efficiency. Best practices show that by acting smartly, the water sector can tackle climate change and achieve energy economy. A water project may reduce emissions by incorporating energy-efficient equipment, capturing biogas to generate electricity, and investing in renewable energy generation, among other methods.

Module 2 is divided into two steps:

Step 1 describes procedures and available online resources for conducting a life-cycle GHG accounting of water-related activities, separating the different steps in the water-use cycle. The output of this step may be used for benchmarking the efficiency of alternative water supply and demand management options (discussed in Step 2).

Step 2 identifies opportunities for GHG reductions and helps users pre-assess the benefits (reduced GHG emissions and reduced carbon pricing) of alternative mitigation strategies.

Step 1

Estimate The GHG Footprint of The Project

SCOPE

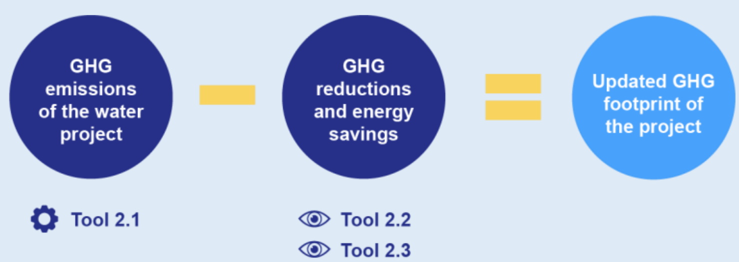
To describe a coherent methodology for assessing the GHG footprint of a new water project and to provide average water sector figures for a preliminary GHG calculation. After completing this step, users will have a clear understanding of how the different processes add up to the total carbon footprint of the project and how the latter compares to the water-sector average and the country's GHG-reduction targets. Properly accounting for GHGs is an important step, not only for ensuring alignment of the project with Paris Agreement and the national and international frameworks described in the previous module, but also to ensure that the project will minimize its carbon footprint.

PROCESS

The calculations focus on the upstream phases of the water-use cycle, including :

- **Extraction and diversion:** emissions generated from removing water from a channel, pipeline, stream, or aquifer.
- **Storage and transfer:** emissions generated from storing water in reservoirs or groundwater banks, and emissions generated from transferring untreated water through aqueducts, canals, and pipelines from the source to the water treatment facility.
- **Treatment:** emissions generated from treating water prior to distribution.

For this preliminary assessment, only Scope 1 and 2 emissions are considered for all sources/facilities that are controlled or owned by the project. This accounts for both direct (e.g., emissions associated with fuel consumption) and indirect (e.g., emissions associated with the purchase of electricity for the operation of a project facility).



TOOLS

TOOL 2.1 A simplified procedure for the assessment of GHG emissions

TOOL 2.2 Opportunities for increased energy efficiency in water facilities

TOOL 2.3 Opportunities for renewable energy in water facilities

OUTPUT

A summary of the GHG emissions and energy consumption across the different phases of the project.

TOOL 2.1

A SIMPLIFIED PROCEDURE FOR THE ASSESSMENT OF GHG EMISSIONS

This tool may be used for a preliminary assessment of the water project's GHG emissions. It should be noted that the calculations to be performed at this stage are based on water-sector averages that may not fully capture the project specifics. Moreover, they are not comprehensive because they do not include Scope 3 emissions from upstream or downstream processing outside the project's organizational boundary. It is therefore recommended that in the subsequent phases of the project, the calculations be revised using (where available) project-specific data (adopted from similar applications or recent studies) and Scope 3 emissions to improve the accuracy of the modeled carbon costs.

Following international practices, the GHG accounting is expressed in terms of water-energy greenhouse gas (WEG) intensity metrics, which describe the GHG footprint of a unit volume of delivered water. The metrics are calculated individually for each step in the water-use cycle and aggregated for a composite GHG metric. Public officials and project developers can use these metrics to benchmark the energy efficiency of the planned project and communicate WEG intensity information to policy makers, funders, and the public in a reliable and transparent manner.

INPUT

1 **Get familiar with the** GHG Protocol Corporate Accounting and Reporting Standard developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The standard provides foundational guidance on GHG accounting principles, defining inventory boundaries, and identifying GHG emission sources.
Specific guidance on water-energy GHG calculations can be retrieved from the World Bank Group's GHG accounting tool,[19] which provides an Excel spreadsheet-based platform for GHG accounting and is accompanied by comprehensive user manuals, and The Climate Registry (TCR), a non-profit North American organization that offers services and tools for accounting and reducing emissions.

2 **Build a GHG inventory, including water-related emissions**
Such an inventory includes Scope 1 and 2 emissions for all facilities/sources under the defined geographic, organizational, and operational boundaries of the project that can be directly tied to any of the steps of the water-use cycle. This automatically excludes activities, such as administration, training, planning, and human resources, which, although related, are not directly contributing to the delivery of water.

[19] https://worldbankgroup.sharepoint.com/sites/WBWaterpractice/SitePages/PublishingPages/Climate%20Change%20Opera-1662054369816.aspx.

A qualitative description of the potential GHG footprint of different water-supply options may be found in **Table 2.1**.

3

Collect data for each step of the water use cycle

To assess GHG emissions and calculate WEG intensity metrics, users will need to obtain access to water delivery and GHG emissions data for all the identified water-related activities. For each step, three emission categories will be calculated (for which data are required):

- The embodied carbon of manufacturing and construction. This may include: the carbon embodied in the civil works for the construction of dams/embankments and the manufacturing of pipes and pumps.
- The energy usage during the capital works (for excavations, civil works construction, and installation of equipment).
- The energy usage during operations (e.g., the energy required to operate pumps or to distill water). The operational energy usage is based on the yearly volume of water delivered.

Water Delivery Data

- Deployable output of source or capacity or pipeline transfer measured in mega-liters (Ml) per day.
- Nominal plant of pump house capacity measured in kilowatts (kW).
- Annual frequency of operation, measured in operational hours per day and days per year.
- Basic geometric characteristic of key plant components (e.g., area of ancillary buildings, piping length).
- Annual volume of water delivered.
- Treatment technologies (e.g., reverse osmosis and nano-filtration methods typically require less energy than earlier desalination methods that heated water for distillation, such as multi-effect and multi-stage flash distillation).

Emission Factors

- Emissions from stationary combustion fuels (e.g., for the operation of a pump and transport fuels).
- Emissions from construction activities.

For a preliminary assessment, users may refer to the default emission factors published publicly in any of the resources listed below:

- National Inventory Submissions 2021 (United Nations Framework Convention on Climate Change (UNFCCC))
- TCR Resource Library
- Emission Factor Database (European Environment Agency (EEA))
- GHG Emission Factors Hub

When site-specific data are available, users are encouraged to customize the general-purpose emission factors to better reflect the project attributes.

4

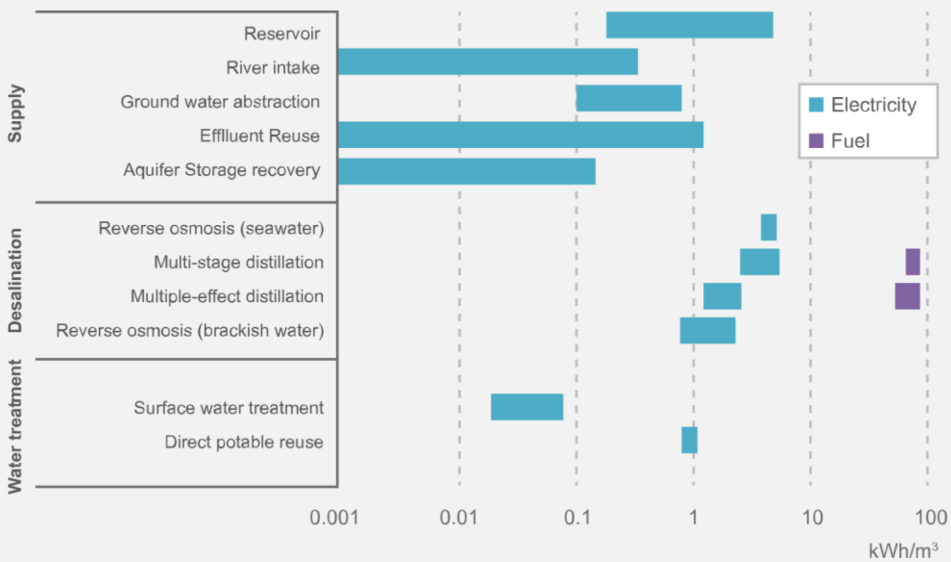
Calculate the total emissions for each step of the water-use cycle:
For each emission category and step in the water-use cycle, add up the emissions from each relevant source or facility included in the GHG inventory. Note that no single source/facility should be counted in more than one category to prevent double counting.

If the above-mentioned information is unavailable (or if project specifics are yet to be determined), a high-level assessment of the GHG emissions may be performed using the information provided in **Figure 2.1.**

To convert kilowatt-hours (kWh) to kilos of carbon release ($kgCO_2$), use appropriate country-specific electricity conversion factors that may be found here:

- Country Specific Electricity Grid Greenhouse Gas Emission Factors (2022)
- Greenhouse Gas Reporting: Conversion Factors 2022

FIGURE 2.1 Energy use for various processes in the water sector



Sources: Reffold, Emma, Feifei Leighton, Fida Choudhury, and Paul S. Raynor. 2008. *Using Science to Create a Better Place: Greenhouse Gas Emissions of Water Supply and Demand Management Options.* United Kingdom Environment Agency; IEA (International Energy Agency). 2016. *Water-Energy Nexus.*
Note: kWh/m3: kilowatt-hour per cubic meter.

5

Calculate the WEG metric of the project
The WEG metric of an individual step is defined as the ratio of the respective emissions sum to the volume of delivered water in the specific step, AF_{step} , (to account for potential differences in the volume of water passing through each step), according to equation 1:

$$WEG_{step} = \frac{(Total\ Emissions)step}{AF_{step}} \qquad \textbf{(Eq. 1)}$$

The composite WEG metric of the project can then be calculated as the aggregation of the individual WEG_{step} according to equation 2:

$$WEB_{total} = \frac{\sum(Total\ Emissions)step}{AF_{total}} \quad \textbf{(Eq. 2)}$$

where AF_{total} is the total volume entering the downstream system (e.g., the distribution system).

6 **(Optional) Use any of the publicly available online tools** to assess the GHG emission of the project or to confirm the calculations already performed.
One such tool is the Energy Performance and Carbon Emissions Assessment and Monitoring Tool (ECAM) developed by the Water and Wastewater Companies for Climate Mitigation (WaCCliM) to assist users in quantifying the GHG emissions of their water and wastewater projects. Assessments are performed in two tiers of increasing detail:

- Tier A approach is appropriate for a very preliminary assessment and can be used with limited data inputs (e.g., country, population, emission factor for grid electricity).
- Tier B assessments require detailed data for each stage of the urban water cycle and provide a more accurate assessment.

7 If more than one project option is examined, **repeat the calculation** for the alternative project options (which may include different water volume, alternative water supply sources, different pump sizes and piping lengths, different treatment technologies).

OUTPUT

Total emission and WEG metric distribution across the different phases of the water-use cycle for the project (and the project alternatives). An overview of the opportunities to reduce GHGs, which will be further refined in the subsequent step.

TABLE 2.1 Preliminary environmental considerations for different water supply options

Options	Sub-types	Details relevant to energy use and carbon emission
Reservoir	• Bankside • Bund Construction • Pumped • Groundwater recharge • Quarry area	• The embedded carbon footprint of construction works is commonly relatively high. • Medium operating carbon cost. • Potential for major impact on local environment.
Desalination plant	• Reverse osmosis • Electrodialysis • Nanofiltration • Offshore	• Treatment of brackish or saltwater to produce drinking water. • Energy usage depends on input and output water salinity, but in general the carbon footprint of desalination is high. • Generates highly saline waste to be disposed of.

Options	Sub-types	Details relevant to energy use and carbon emission
		• Treated water needs hardening in order to reduce GHG emissions mixing with other sources of water.
Groundwater	• Boreholes • Aquifer storage recovery	• Accounts for large proportion of public supply. • Energy consumption depends on borehole depth. • Treatment cost depends on aquifer type but generally lower than for surface water source.
River abstraction	• Water treatment works and reservoir	• Relatively low cost to construct/operate. • Treatment cost depends on surface water quality. Higher water quality may result in lower treatment cost upfront, but it also requires more stringent wastewater discharge standards upstream (which will increase GHG emissions). • Depending on land use in upstream catchment area, higher water quality may also result in better agriculture practices upstream, which will also reduce GHG (win-win situation).
Transfer	• Pipelines	• Energy depends on pumping length/head/capacity. • Significant energy savings can be accomplished by applying energy efficiency approaches (pipe dimension optimization to incorporate energy consumption component, pipe material selection to consider pipe production carbon print).

Source: Reffold et al. 2008.

TOOL 2.2

OPPORTUNITIES FOR INCREASED ENERGY EFFICIENCY IN WATER FACILITIES

When entering the tool, the users should already possess a preliminary overview of the energy consumption profile of the water facility and its life-cycle GHG footprint. They should also have identified energy-consuming processes/components that contribute substantially to an increase in carbon pricing of the facility. The aim of this tool is to guide them on the recommended strategies to increase energy efficiency in the water facility and on the potential life-cycle savings from committing to an energy efficiency strategy.

Although the tool primarily focuses on strategies for improving energy efficiency in the upstream process of water use (see the Typologies section of this toolkit), over which the facility operator has full control, it recognizes that significant energy savings can only be achieved via a holistic water management approach that runs through the entire water-use cycle. In this category, one may find water efficiency options that promote the sustainable use of water (by the end users), which in turn reduce the water demand and hence the amount of energy needed to treat, distribute and dispose of water. Moreover, efforts to improve water efficiency can extend the life of existing infrastructure due to lower demand, thus avoiding the need for costly future expansions. A quantitative example of the incurred benefits of implementing a water conservation strategy (measured in terms of reduced GHG emissions and reduced carbon pricing) is provided in **Box 2.1**. Reduction in energy use can also be achieved by water loss prevention through the installation of appropriate leakage detection systems, as well as by promoting stormwater retention, which will provide the additional benefit of attenuating the surface runoff during extreme rainfall events.

INPUT

1

Assess the energy baseline and the GHG footprint of the "do nothing" option

For this, users are referred to the output of **Tool 2.1**. Note that the "do nothing" option refers to a water facility for which no specific low-carbon measures are pursued. The energy baseline of this option can be used to benchmark the success of the implemented strategies.

2

Target priorities

Go through the different phases of the water-use cycle (that apply to the project under consideration) and identify activities and operations that consume the most energy and for which interventions would be extremely beneficial. Where possible, prescribe target performance indicators (e.g., for the operation of machinery equipment, water loss thresholds).

3

Review applicable energy-efficiency approaches and combine them to structure a low-carbon strategy

In this toolkit, opportunities for improving energy efficiency in the upstream processes of water facilities fall into five categories: i) planning decisions, ii) equipment upgrades, iii) operational modifications, iv) modifications to facility buildings, and v) on-site renewable energy generation.

Planning decisions are made about the siting of the water facility. Distance and topography are important factors to consider. By reducing conveyance distances and using gravity rather than pumps, water utilities can yield reduced energy requirements.

Equipment upgrades focus on replacing items such as pumps and blowers with more efficient models (e.g., smart pumping systems control flow rate and power to match the pump output exactly to the system conditions, and can detect and protect against unusual operating conditions); see **Box 2.2**.

Operational modifications include provisions for installing internet of things (IoT) technologies to track, measure, report on and audit energy usage, and modifications to the operational schedule for increased energy cost savings (see examples in **Box 2.3**).

Modifications to facility buildings and equipment typically include changes to the lighting, heating, and cooling equipment in order to reduce the amount of energy consumed by the facility buildings themselves.

On-site renewable energy generation refers to the installation of turbines, solar panels, and other renewable energy technologies in water facilities in order to reduce energy requirements and increase the energy resilience of the facility. Specific guidance on this particular matter is provided in Tool 2.3.

A non-exhaustive list of specific energy efficiencies that can be applied to different phases of the water-use cycle is provided in **Table 2.3.** Users are advised to consult the table and identify opportunities for improvement that best suit their project profile.

4

Appraise the potential benefits of the low-carbon strategy

These relate to GHG emission reductions and/or reduced cost of energy. To monetize the benefits from this category, users should first derive the improved GHG footprint of the facility (to account for changes in capacity/efficiency of equipment, operational savings, reduced GHG emissions introduced by modern water treatment processes). The footprint is then converted to carbon cost using adequate conversion factors (as explained in Tool 2.1).
The average incremental carbon cost (AICC) of the investment can then be estimated as the ratio of the net present value (NPV)[20] of the updated carbon cost of the facility over the net present value of the water delivered by the facility, according to the formula:

$$AICC = \frac{CC_{NEW}}{Water}$$

Where CC_{NEW} is the NPV of new carbon cost (i.e., original carbon cost of the facility minus savings from the implementation of the low-carbon strategy) measured in dollars and $Water$ is the NPV of water delivered or saved (measured in mega-liters).

5

Identify energy-efficiency co-benefits and describe how they can positively impact the overall socioeconomic value of the investment. Examples include:

Public image improvement and responsible government stewardship of tax dollars, which is important for enhancing the public acceptability of the PPP project.

6. **Public health protection**. Improvements in the energy efficiency of water facilities can reduce air and water pollution from the power plants that supply electricity, resulting in cleaner air and human health benefits.

7. **Economic growth through job creation and market development.** Investing in energy efficiency can stimulate the local economy and spur the development of energy-efficiency service markets. Most of these jobs are performed locally by workers from relatively small local companies.

8. **Energy security and sustainability.** Improving energy efficiency reduces electricity demand and hence the risk of blackouts during high energy demand periods, and energy sustainability lowers the need to build new power plants.

9. **Contribution to climate resilience**. For example, equipment upgrades in the piping system will reduce water leakages and as a result the overall flow into collection systems. This will lower the risk of combined sewer overflows during flood events.

[20] The NPV is the sum of the annual carbon costs/savings over the planning period, with future costs/savings discounted using proper discount rates.

Monetizing the above benefits is not straightforward and is beyond the scope of this toolkit to propose a fully quantified appraisal methodology in that respect. A preliminary qualitative description of the potential benefits is considered adequate for the purpose of this preliminary assessment.

6

Consult with local experts and general contractors to understand the additional costs associated with the implementation of the low-carbon strategies. In general, operational modifications do not require significant capital investments and may result in greater savings than equipment upgrades. Users should therefore exhaust the possibilities of implementing such "low regret" solutions before experimenting with resource-demanding alterations of the facility design or equipment.

7

(Optional) Repeat the process for alternative low-carbon strategies.
Qualitatively compare the cost/benefit merit of each strategy and qualify those that offer higher value to the project. Qualified strategies will continue to the next phase of PPP preparation, where the economics of the investment and the VfM will be analyzed in greater detail (**Module 3**).

OUTPUT

Re-evaluated estimation of the energy/GHG footprint of the water facility, accounting for low-carbon interventions and a qualitative appraisal of the associated costs and benefits.

BOX 2.1 MAXIMIZING GHG REDUCTION THROUGH A HOLISTIC WATER MANAGEMENT APPROACH

In order to support the United Kingdom's (UK's) government imperative for reducing GHG carbon emissions in the water utility sector, the UK Environment Agency (Reffold et al. 2008) analyzed the life-cycle GHG emissions associated with a variety of supply-side and demand-side interventions. The analyses demonstrated that:

- Eighty-nine percent of carbon emissions in the water system is attributed to "water in the home" and includes the energy for heating water. As such, simple demand management measures which aim to reduce the use of hot water have significant potential to diminish the carbon footprint of the water supply use-disposal system.
- Increasing water production (to meet rising demands) through new supply-side measures (e.g., new reservoirs) creates significant carbon emissions for all explored alternatives.
- Targeted changes in demand-management options compare favorably to supply-side options in terms of overall lower carbon emissions. A minimum GHG footprint can be achieved through combinations of various demand-management options.

TABLE 2.2 Example carbon emission reductions that can be achieved by applying water metering approaches and low-flush options in toilets across the different phases of the water-use cycle

Water System Components	**Carbon Emissions**—Baseline		**Reduced Emissions**—1,000 homes	
	Water system tCO2e/Ml	1,000 homes tCO2e/year	Meter, tCO2e/year (10% water saved)	Toilet, tCO2e/year (9.4% water saved)
A. Source/conveyance	0.030	3.8	-0.4	-0.4
B. Treatment	0.136	17.4	-1.7	-1.6
C. Distribution	0.105	13.4	-1.3	-1.3

D. Household	6.221	794.7	-79.5	0
E. Wastewater	0.476	60.8	-2.4	-2.3
Total carbon	**6.968**	**890**	**-85**	-5.5

Source: Reffold, E., Leighton, F., Choudhury, F., Rayner , P.S., (2008), Greenhouse gas emissions of water supply and demand management options, Science Report – SC070010, Environment Agency

Note: tCO2e/Ml: ton of CO2 equivalent per megaliter; tCO2e/year : Ton of CO2 equivalent per year

BOX 2.2 ENERGY SAVING ESTIMATES IN WATER SUPPLY SYSTEMS

There are two areas with the most potential: pumps of most types and functions, and desalination processes. Potential energy savings include:

PUMPS AND PUMPIMG

POTENTIAL RANGE: 5-30%

- 5-10% by replacing pumps of older technology
- 3-7% through installation of new pumping technology
- Gains up to 30% by more closely matching pumps to their duties (e.g., use of variable speed drivers (VSDs), automated control systems).

DESALINATION PLANTS

POTENTIAL RANGE: Up to 60%

- Reductions up to 60% in the energy consumption of the reverse osmosis process by adding energy recovery devices (ERDs) to recover the pressure energy of the concentrate.

OTHER

- Up to 20% by managing water demand.
- Up to 15% from improvements in building/facility services.

TABLE 2.3 Opportunities for GHG reduction and energy savings in the upstream phases of water projects

	Indicative Measures
Planning decisions	Extraction • Capture energy from water moving downhill to reduce pumping requirements. • Right-sizing pump systems by looking at the water system comprehensively (e.g., changes in consumers' demand will modify pumping requirements). • Install parallel pumps for increased flexibility in flow rates (e.g., combine small pumps to operate at low flow rates and large pumps to cope with the maximum design flows). This will ensure that the pumping systems will not operate far from their best efficient points (BEPs) which will increase energy efficiency. Storage, conveyance and treatment • Use downhill pipes to minimize the use of pumps/increase the elevation of inlet structures with respect to the reservoirs.

	Indicative Measures
	• Optimize pumping configuration to minimize pressure drops (e.g., by avoiding sharp bends, expansions, and contractions and by keeping the piping as straight as possible). • Optimize energy consumed for desalination by preferring brackish water sites where possible. • Clear vegetation prior to filling reservoirs to reduce GHG emissions from decomposing organic matter.
Equipment upgrades	Extraction • Prefer/replace submersible borehole pumps from/with line shaft pumps. • Use variable frequency drives (VFD) in pumps to adjust pump speed and meet changes in demand, thus reducing the energy loss for throttling or bypassing excess flow. • Use automatic control systems in multi-pump stations to allow for an optimized automatic switching and pressure-dependent use of the pumps. This will allow the facility to benefit from reduced energy consumption, reduced risk of physical damages (in case of hydraulic impacts), and overall increased service life of the pumping equipment. Storage, conveyance and treatment • Use/upgrade pumping equipment (e.g., VFD drivers, automatic control systems). • Prefer low-loss components (e.g., valves) that have higher upfront costs but offer reduced life-cycle costs during system design. • Invest in energy-efficient motors (e.g., inverters).
Operational modifications and modifications to facility buildings	Measures that apply to all stages • Invest in system-wide SCADA systems to gather and analyze operational data in real time. This will allow rapid identification of flows (e.g., chemical imbalances, leaks, and overflows) and continuous rebalancing of processes and systems to maximize efficiency and reduce system downtime. • Use water metering to monitor system flows and track water losses. • Integrate active leakage control systems for targeted detection of unreported leaks. • For existing facilities: rehabilitate leaking components (e.g., retrofitting and replacement of plumbing fixtures like cisterns, taps, pipes, and valves). • Reduce energy costs by reducing peak power demand by shifting some pumping and treatment operations to the off-peak period(s).[21] • Install power capacitors to reduce electric usage penalties due to low power factors.[22] • Establish and implement a modern energy management plan. (Look for relevant guidance in ISO 50001.[23])

[21] The savings from such an approach should be carefully assessed because off-peak pumping often creates leakages.
[22] Power factors below 1.0 require an electric utility to supply more current than the necessary minimum, increasing generation and transmission costs. Sometimes electric utilities charge a fee for power generation below 1.0.
[23] ISO (International Organization for Standardization). 2018. "ISO 50001: 2018: Energy Management Systems—Requirements with guidance for use."

	Indicative Measures
	• Enhance lighting and space conditioning efficiency in offices and control rooms (e.g., installing high-efficiency LED-lighting, investing in HVAC improvements[24]).
On-site renewable energy generation	Measures that apply to all stages Options for generating green energy include solar panels, wind turbines, fuel cells, and microturbines. Utilities can purchase and operate their own renewable energy generation equipment or contract with a third-party provider that owns and manages the green power on-site for them (see also Tool 2.3).

BOX 2.3 EXAMPLES OF OPTIMIZED OPERATIONS IN WATER FACILITIES[25]

In **Fortaleza, Brazil, the local water utility** implemented measures to improve the distribution of water while reducing operational costs and environmental impacts. With an investment of only $1.1 million to install an automatic control system and other simple measures, the company reduced electricity consumption by 88 gigawatt-hours (GWh) and saved $2.5 million over four years. During the same period, the utility was able to establish an additional 88,000 new connections without increasing overall energy use.

The **City of Oswego, New York, United States,** partnered with an energy performance contractor to identify several improvements to the water and wastewater treatment systems, including increasing pumping efficiency, an automated control system that modulates pump speed to maximize efficiency, a new supervisory control and data acquisition (SCADA) system, and a lighting system replacement. The plant managed to reduce energy consumption by more than 25 percent.

Sources:

- Liu, Feng, Alain Ouedraogo, Seema Manghee, and Alexander Danilenko. 2012. *A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities*. World Bank.
- Victoria State Government Environment, Land, Water and Planning. "Projects reducing water sector emissions."

[24] HVAC systems can have high initial costs but are generally cost-effective over the life of the investment. Efficient HVAC systems can reduce energy use by 10 percent to 40 percent.

[25] The examples described provide data about the energy-saving potential in water project operations, regardless of the procurement method (public procurement or PPP).

TOOL 2.3

OPPORTUNITIES FOR RENEWABLE ENERGY IN WATER FACILITIES

Following worldwide efforts to transition to green energy, water supply projects are increasingly using renewable solutions for energy generation and efficiency. Several factors, including reduced costs, improved reliability of old technologies and new technological advancements, booming private sector interest, and environmental co-benefits, among others, have been pivotal for their uptake in the sector. This tool (that will be used in combination with Tool 2.2) aims to assist users in discovering the opportunities for renewable energy in water supply projects, recognizing their role in revolutionizing water production processes, and understanding their life-cycle benefits.

INPUT

The tool can be used for a preliminary screening of the most promising currently available renewable technologies, representing different maturity levels.

1 **Review renewable energy approaches that are relevant to the project under consideration.** Opportunities for renewable energy in the upstream processes of water production fall into four categories:

- **Renewables for on-site energy generation.** Technologies may include:
  a) Mini-hydro (i.e., hydroelectric generation from smaller projects installed on rivers and streams, which does not require large dam infrastructure).
  b) Floating solar photovoltaic (PV).
  c) Small-scale desalination using wave, tidal, solar and geothermal resources.
- **Renewables in water pumping applications** to offset energy demands for pumping, particularly in off-grid applications where the cost of pumping is higher.
- **Improved energy storage technologies and practices to further increase renewable energy use (in water pumping applications).** This may include activities that:
  a) Exploit pumped water storage to overcome intermittency issues with renewable energy pumping technologies (e.g., synchronize pumping activities with renewable energy generation profile to replenish stored water that will be later released for electricity generation—when the renewable energy will be unavailable).
  b) Incorporate emerging technologies in energy storage systems (ESS) for capturing and storing renewable energy. Depending on the project specifics, a combination of available technologies may be required (e.g., batteries for short-term energy storage, concentrated solar power plans for stabilizing the electric grid, and energy storage in the form of renewable fuels produced by surplus power).

- **Offsetting energy needs** by purchasing energy generated from renewable sources (e.g., solar or wind parks).

A comprehensive list of specific renewable energy technologies for water supply projects is presented in **Table 2.4**. The maturity level of the technology is also described, followed by application examples (where available).

2 **Assess the suitability of the envisaged renewable solution**.

Factors to consider when assessing the suitability of the renewable energy solution within the project context are:

- **Technical experience:** Does the public authority have previous experience with the specific technology? Can the public authority handle the design, procurement, installation, commissioning, operation and maintenance, and monitoring of the renewable technology?
- **Technology readiness**: What is the technological maturity level of the envisaged solution? Does it incorporate unproven technologies that have not been market tested?
- **Cost efficiency:** Is the cost of the investment reasonable when compared to traditional approaches? A systematic way to appraise the cost efficiency is by comparing the levelized cost of the energy (LCE) produced with renewable sources, with the LCE generation from conventional fuel generators accounting for the lifetime costs of the system (i.e., initial capital expenditure operation, maintenance, construction cost, taxes, and other financial obligations/incentives).
- **Knowledge transfer potential:** Can the project benefit from international technology/knowledge transfer from countries that have already successfully implemented the envisaged solution?

3 **Explore financing schemes/incentives to support the design, acquisition, operation and maintenance of renewables and structure a preliminary business model.** The business model will at least describe:

- **Renewable service provider** (e.g., PPP sponsor, sub-contractor of the PPP sponsor with experience in the envisioned technologies, independent renewable service provider).
- **Reimbursement scheme** (e.g., power purchase agreement (PPA), reimbursed in a pre-negotiated way so that the burden of upfront cost is eased for all parties involved).
- **Financial incentives** (e.g., subsidies from involved ministries, feed-in tariffs, bonuses for renewable energy certificates, green bond market products).

TABLE 2.4 A list of renewable technologies encountered in water supply projects

Category	Technology	Description	TML[26]	Applications
Solar	**Solar water pumping**	Extracting water from a source (well, pond, river, storage tank) using the sun's energy.	High	Popular in vast areas of Africa, North America, Oceania, and Asia, where fuel can be expensive to transport, electrical grids are absent or unreliable, and access to water points limited, but solar irradiation is fairly constant and high.
Solar	**Ground-mounted solar**	Using PV panels to covert solar radiant light and heat from the sun to electricity.	High	Widespread capability for the use of large-scale solar technologies in water supply/treatment plants to offset power consumption.
Solar	**Floating solar PV**	Floating panels use the direct sunlight and reflected light from the water surface to generate energy. Due to the cooling effect of water, floating solar projects can be up to 15 percent more productive in comparison with terrestrial solar projects.[27]	High	Growing deployment of large-scale floating solar plants, including examples in Japan, Korea and the United States (US). Example: An array of 12,000 solar panels sprawling across a retention pond in Sayreville, New Jersey, was installed to power the water treatment plant that holds some of the town's water supply.
Solar	**Flexible (or submerged) PV concepts**	Instead of incorporating rigid crystalline PV panels (as in conventional PVs), utilize flexible thin film PVs to generate electricity. Due to their flexibility, they can endure loading from tides,	Low	The technology has been tested only in small-scale test sites. Different flexible PV prototypes have been developed and are about to enter the market: 1. SUNdy, developed by the Det Norske Veritas

[26] Estimate based on literature review.
[27] According to the Environmental and Energy Study Institute.

Category	Technology	Description	TML[26]	Applications
		high winds and waves, and hence can be installed in marine environments.		2. MIRARCO's flexible PV 3. SCINTEC submergible floating PV
Solar	**Solar power desalination**	In direct solar desalination systems, solar energy is used directly for the production of distilled water in a solar collector, with solar still as the most representative technology; whereas in indirect solar desalination systems, solar energy is harvested either by solar thermal collectors to provide heat or photovoltaic panels to generate electricity for thermal or membrane desalination technologies such as multi-effect desalination (MED), multi-stage flash desalination (MSF), membrane distillation (MD) or reverse osmosis (RO).	Medium	Large-scale solar desalination projects have been developed in the Middle East. There is emerging potential for small-scale solar thermal for MED desalination processes. Example: A 110 MW solar park will power the Al Jubail 2 water desalination plant on the east coast of Saudi Arabia. The deployment of solar energy at the site is aimed at cutting carbon dioxide emissions by 155 megatonnes annually and reducing electricity consumption. The clean electricity from the solar park will also displace the consumption of 410,000 barrels of crude oil annually at the water desalination plant which has a production capacity of up to 1 million cubic meters per day.
Wind	**Small- or large-scale wind energy generation**	Wind energy, or wind power, is created using a wind turbine to channel the power of the wind to generate electricity.	High	Widespread capability for implementing wind technologies across the water sector for reduced energy consumption.
Wind	**Wind power pumping**	Windmills start lifting water when wind speed approaches 8–10 kilometers (km) per hour. Normally, a windmill is capable of pumping water in the range of 1,000 to 8,000 liters (lt) per hour, depending on the wind speed, the	High	May find application in decentralized water supply projects in rural and remote windy areas. Example: A wind-powered water pumping system was implemented to facilitate the extraction of well water in the Coclé province of Panama using renewable energy

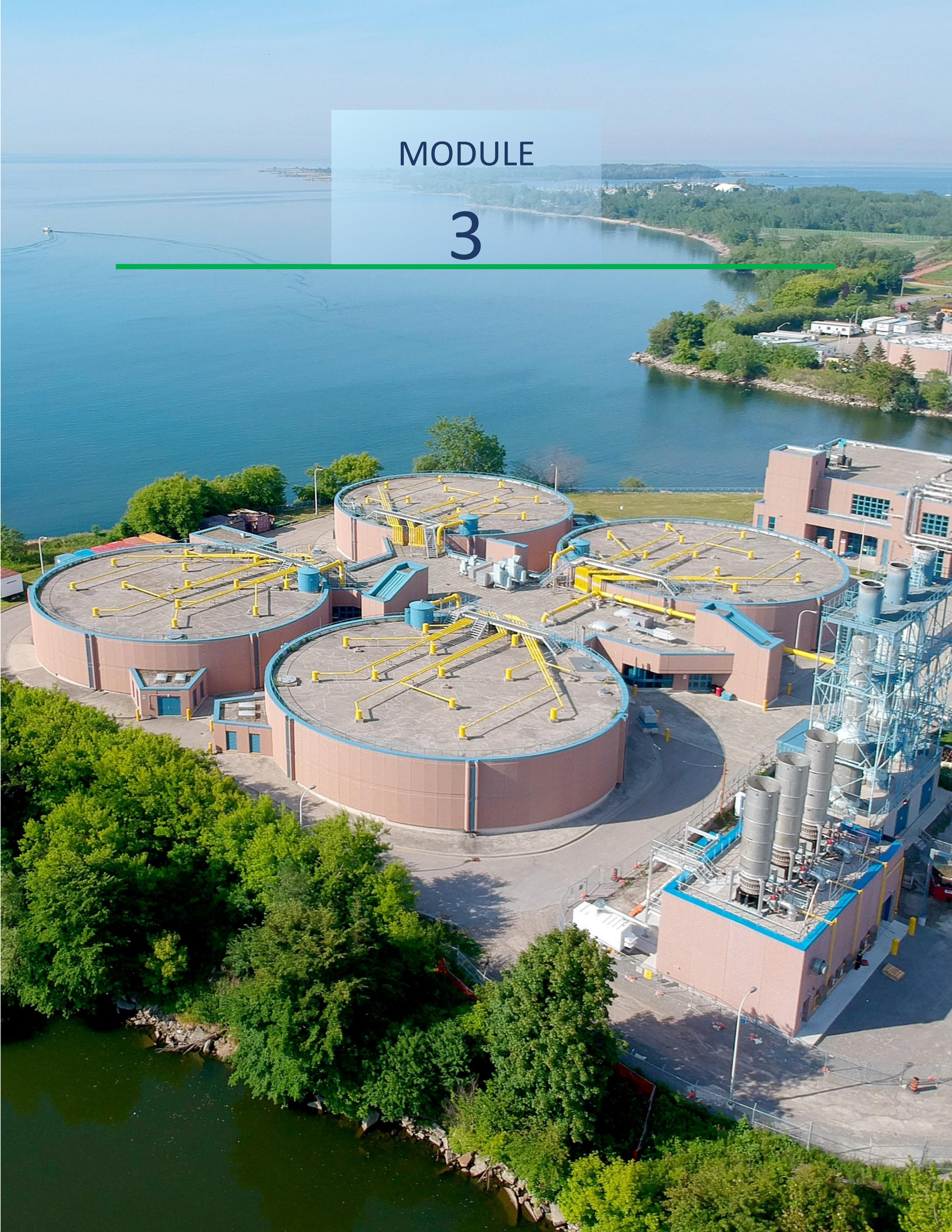
Category	Technology	Description	TML[26]	Applications
		depth of the water table, and the type of windmill.		sources. The established solution led to substantial savings (compared to fuel-based methods). Under favorable conditions, it is estimated that the system produces 30,000 liters of water per month, which supplements the amount of water produced by the existing surface intake system.
Water	**Tidal/wave energy for desalination**	Harnessing the tidal movement of seawater to generate energy.	Low	No practical applications at current stage.
Water	**Micro/mini hydro**	They are usually run-off schemes using turbines to power a generator that produces electricity. Micro-hydro solutions may produce from 5 kW to 100 kW of electricity, whereas mini-hydro solutions can generate 100 kW to 1 MW of electricity.	High	Widespread use in water projects.
Water and solar/wind	**Pumped storage integration with renewables**	Using pumped storage capacity (PSC) for hydroelectric generation by exploiting the vertical drop between upper and lower reservoirs. PSC can be used either as a standalone off-grid backup scheme (for an output of less than 10 kilowatt-hours per day) or as additional on-grid generation scheme (for an output of greater than 10 kilowatt-hours per day). The PSC	High	Widespread use in water projects.

Category	Technology	Description	TML[26]	Applications
		configuration can generate hydroelectric energy either on demand, or at pre-determined time slots: • At ***night***, when solar energy is not available (***in the off-grid configuration***)—then refill the tank during the day, when an excess of renewable energy is available. • During the ***day***, when the electric energy demand curve is at peak (***in the on-grid configuration***)—then refill the tank during the night, when the electrical energy (kWh) is cheaper.		
Water and solar/wind	**Injector-generator (INGEN) system**	The technology operates at the nexus of energy and water to enable predictable delivery of power from intermittent sources and large-scale deployment of renewable energy. The system uses the pressure in underground wells to generate electricity and is unique in its ability to be installed in flat areas—eliminating typical Pumped Storage Hydropower (PSH) geographical limitations (i.e., finding high and low elevations in close proximity).	Low	Available technology: Quidnet. Example: Quidnet has partnered with the US Department of Energy (DOE) Water Power Technology Office through its HydroWIRES Initiative to develop a reversible injector-generator that will enable deployment of modular hydropower conversion in high-pressure pumped hydro applications.

Category	Technology	Description	TML[26]	Applications
Geothermy	**Geothermal energy**	Heat energy from within the earth is captured and harnessed for electrical power generation. In particular, geothermal desalination refers to the production of fresh water using heat energy extracted from underground rocks.	Low	Several small-scale pilot projects and test plans have been carried out using standalone geothermal desalination or any number of combinations. Examples include: 10. A low enthalpy geothermal energy driven water desalination unit on Milos island in Greece 11. A geothermal desalination project pilot plant on Kimolos island, Greece (producing 3.24 cubic meter of fresh water per hour (m3/h)) 12. A desalination prototype utilizing the Aero-Evapo-Condensation Process (AECP) was developed in Tunisia.

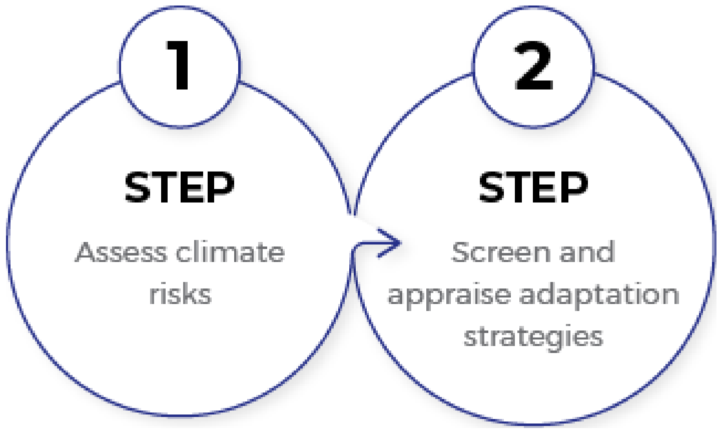
Note: TML stands for Technology Maturity Level

MODULE 3



Module 3

ASSESS CLIMATE RISKS AND PLAN ADAPTATION STRATEGIES



Climate change is impacting water projects in several ways, and may impact both the supply and demand side of the project as well as the longevity of the water infrastructure itself. Supply-side pressures decrease the fraction of water that is available for use (e.g., due to increased evaporation caused by rising temperatures and decrease of precipitation), whereas demand-side pressures change the seasonal and daily water-use patterns challenging operations. Moreover, extreme climate hazards (e.g., flood events) may severely impact the structural integrity of water-related infrastructure with cascading (operational and maintenance) losses. Topping it all off, the performance of water systems is also influenced by several other non-climate uncertainties with impacts that in many cases are greater than that of the climate. Water use scenarios are "notoriously difficult to make" and human population growth, one driver of water demand, is subject to highly volatile and poorly understood factors[28] (Arnell 1999, Cohen 2003).

As a response to this uncertain future, the engineering community has devised highly sophisticated methodologies to assist in making water system planning decisions. All of them have been built on the same underlying concept: System alternatives are stressed across multiple scenarios (simulating the range of potential changes in the natural system and the human factor) in order to discover a robust scheme that is less likely to fail (examples of such methodologies are briefly discussed in **Box 3.1**). Of course, the implementation of such technical approaches is practically unfeasible during the inception stage of any project (and in particular of a PPP project) when availability of both data and resources is limited, and decisions are usually performed using educated assumptions and the in-house capabilities of the public authority. Further guidance on applying these approaches may be found in the WBG's

[28] Arnell, N. (1999) "Climate Change and global water resources", *Global Environmental Change*, **9**, pp. S31-S49; Cohen, J. (2003) "Human Population: The Next Half Century", *Science*, **302**, pp. 1172-1175

resilient water supply and sanitation (WSS) road map[29] and the "Resilient Water Infrastructure Design Brief,"[30] both of which are informed by the Decision Tree Framework.[31]

To assist the preliminary planning decision of water projects in the context of a changing climate, this module presents a qualitative threshold-based approach that accounts in a simplified manner for the uncertainties associated with climate and non-climate factors. The approach is divided into two steps:

In **Step 1** users recognize the various ways a water project can be negatively impacted by changing climatic conditions.

In **Step 2** users devise strategies to alleviate these impacts, which are then appraised for their costs and benefits.

BOX 3.1 APPROACHES TO ASSIST DECISION-MAKING IN WATER PROJECTS

Scenario-based or top-down approaches, which use climate change projection data to inform decision-making. Projections from general circulation models (GCMs) are often downscaled to sub-regional spatial scales (tens of kilometers) for impact assessments. This climate information may be coupled with other models (e.g., hydrologic or flood) to predict a system response. Risk is based primarily on the consequences from a damaged or failing system under the scenario being considered (Freas et al. 2008).

Decision-scaling, which consider how changes in climate will impact performance based on the current capacity of systems. These evaluations will produce thresholds for failure or damage. Risk is gauged based on the likelihood of exceeding thresholds using GCM projections and consequences from a failing or damaged system (Brown 2011).

Robust decision-making approaches, which apply multiple scenarios derived from GCM projections to create ensembles of plausible futures. The performance of adaptation options is considered across these scenarios to identify those options that reduce risk across all or most scenarios and avoid unacceptable outcomes or worst-case scenarios (Lembert and Groves 2010).

Sources:

1. Freas, K., B. Bailey, A. Munevar, and S. Butler. 2008. "Incorporating Climate Change in Water Planning." *Journal of the American Water Works Association* 100(6): 92–99.
2. Brown, C. 2011. "Decision-scaling for robust planning and policy under climate uncertainty." Background paper for World Development Report. World Bank, Washington, DC.
3. Lembert, R.J., and D.G. Groves. 2010. "Identifying and evaluating robust adaptive policy responses to climate change for water management agencies in the American west." *Technological Forecasting and Social Change* 77: 960–974.

[29] WBG (World Bank Group). 2018. *Building the Resilience of WSS Utilities to Climate Change and Other Threats: A Road Map*. https://openknowledge.worldbank.org/handle/10986/31090.

[30] WBG. 2020. "Resilient Water Infrastructure Design Brief." Water Global Practice Working Paper. https://openknowledge.worldbank.org/bitstream/handle/10986/34448/Resilient-Water-Infrastructure-Design-Brief.pdf?sequence=5&isAllowed=y.

[31] Ray, Patrick, and Casey M. Brown. 2015. *Confronting Climate Uncertainty in Water Resources Planning and Project Design: A Decision Tree Framework*. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/22544.

Step 1

Assess Climate Risks

SCOPE

To identify and qualitatively assess (high, medium, low) the climate risks that may potentially affect operations and revenues.

PROCESS

The methodology for assessing climate risks is described in detail in the Umbrella Toolkit (Modules 1.2 and 2.1). The underlying assumption is that the risk depends on the intensity of the hazard, the likelihood of having a hazard of such intensity affecting the project, and the severity of the impact, according to the equation:

RISK = [HAZARD x LIKELIHOOD] x IMPACT

The process begins with the identification of climate threats potentially affecting the project. Then the intensity and likelihood of the identified threats are considered for a qualitative hazard evaluation on a scale from low to high. This is performed for different climatic futures (representing different climate projections). Next, the impacts of each hazard are assessed similarly to derive the climate risk matrix of the water project. The process is assisted by four tools outlined below:

TOOLS

TOOL 3.1 Mapping climate threats considering future projections
TOOL 3.2 Assessment of climate impacts
TOOL 3.3 Assessment of climate risks
TOOL 3.4 Evaluation of climate-induced externalities and impacts

OUTPUT

- A qualitative risk matrix of the water project.
- A prioritization/ranking of the most significant risks that will be passed on to **Step 2** for adaptation planning.

TOOL 3.1

MAPPING OF CLIMATE THREATS CONSIDERING FUTURE PROJECTIONS

In the context of this toolkit, the threat is defined as any circumstance, action, or event that might exploit the potential vulnerabilities of the system (i.e., the susceptibility or inability of the system or the system's components to cope with climate variability and climate extremes) with the potential of adversely impacting the revenues/safety/availability of the infrastructure. The threat could be:

1. **An acute hazard** that may potentially damage or reduce the functionality of the infrastructure (or of an infrastructure component). For example, damage to a critical pump station caused by a flood surge will obstruct water feeding to the process tanks, rendering the facility inoperable.
2. **A chronic change in climate patterns** impacting water supply and demand. For example, a gradual increase in the mean temperatures will increase evapotranspiration from the vegetation coverage and evaporation from surface water bodies, hence it will decrease surface water supplies and groundwater recharge, permanently hampering the supply capacity of the system availability for exploitation by the facility. Moreover, increased temperatures (and prolonged heat waves) may increase daily peak demand beyond the operational capacity of the facility.
3. **A multiplier of a climate stressor to an already recognized external threat** of the system (e.g., frequent loss of power or higher operating cost caused by climate pressures on the energy sector). This type of threat is separately covered in **Tool 3.4**.

INPUT

The tool assists users in identifying and mapping the climate threats to which the water facility may be exposed throughout its lifetime. The tool provides guidance on how to screen threats and how to qualitatively assess their severity and likelihood of their occurrence.

1 **Decide on the timeframe of the assessment**

The minimum timeframe for assessing climate hazards will be the PPP life cycle. However, the public party may wish to extend the timeframe of the study, given that the life cycle of the infrastructure may be longer than the duration of the PPP contract (e.g., infrastructure design life).

2 **Explore the different ways the changing climate can threaten the water facility.**

In general, the performance of a water facility can be challenged by any of the following climate threats (chronic and acute):

Chronic threats

- **Drought** changes the water levels in aquifers and reservoirs, reduces the water surface flows, and accelerates snowpack decline.
- **Saltwater intrusion** into aquifers reduces water quality and increases water treatment costs.
- **Algal bloom and degraded water conditions** in low-flow areas compromise water quality and increase water treatment costs.
- **Soil erosion** reduces surface water storage capacity, hence system redundancy, and increases infiltration costs for contaminant removal.
- **Coastal erosion,** which may increase due to sea rise and storm surges, could cause structural damage to components located near the shore,
- **Groundwater table rising** Groundwater table rising may cause soil subsidence or damage to water infrastructure due to increased buoyancy.

Acute hazards

- **Flooding and coastal storm surges** cause temporary inundation of treatment plants, intake facilities, water conveyance and distribution systems.
- **Extreme heat** increases water demands on very hot days that may exceed the daily outflow capacity of the facility.
- **Forest fires** can cause an increase in peak runoff and flash floods from affected areas, which in turn will decrease groundwater recharge and increase sedimentation in reservoirs, diminishing their capacity and their effective service lifespan. In reservoirs, increased pollutant loads could result in higher turbidity, algal blooms, and subsequent higher treatment costs.
- **Tropical storms and cyclones** can damage the water facility infrastructure, either directly (e.g., due to fallen trees on surface pipelines) or indirectly, by destroying the coastal or riparian ecosystem which serves as a buffer zone for the inland infrastructure.
- **Landslides** can contaminate water and cause structural damage to components of the water supply system depending on their location, including conveyance pipelines.
- **Extreme winds and hurricanes** may damage tall water tanks, indirectly affecting either the underlying water supply infrastructure or the power supply.

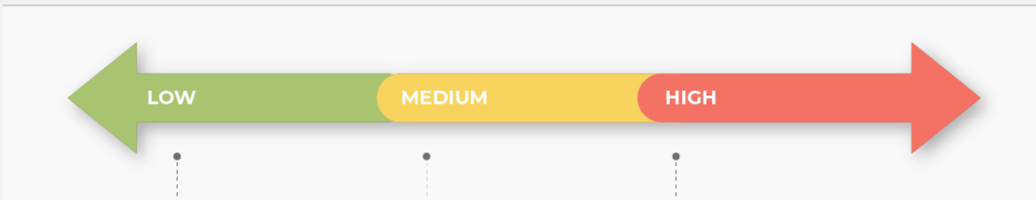
Use the online resources of **Table 3.1.** to identify which of the above threats apply to the infrastructure's regional setting. Complete the list of threats as necessary to also include project-specific threats.

3 **Tap into local knowledge and experience to confirm/revise hazard findings**

This may include already available regional impact maps and previous hazard studies. Past experience in the area can also provide a foundation for identifying the most frequently encountered climate threats or characterizing high-risk regions (e.g., flood plains). Advice on regional risks may also be sought from local contractors or district engineers.

4 **Estimate the current threat level** (applies only for acute hazards)

Use the qualitative scoring scale provided below to characterize hazard severity as a function of the intensity of the hazard and its likelihood of occurrence (or frequency of the event).



LOW
The hazard is not likely to occur during the timeframe of the assessment, and if it occurs its intensity will be low.

MEDIUM
A hazard of moderate intensity is expected to occur at least once during the timeframe of the assessment

HIGH
Hazards may occur several times during the timeframe of the assessment, and their intensity is expected to be relatively high.

5 **Determine the climate-change trend (i.e., increasing, decreasing or stable) for the identified climate threats.**

In **Table 3.2**, each climate threat is associated with one or more primary climate variable(s): temperature, precipitation and sea-level rise. For the sake of this preliminary analysis, it is assumed that any change in the primary climate variables will affect the climate threat in the following ways:

- 1. Increasing severity:
  - If the trend of the primary variable is increasing and the threat-variable correlation is positive. For example, the flood threat is positively correlated with precipitation, and as such the projected increases in precipitation are translated into increased severity of future flood events.
  - If the trend of the primary variable is decreasing and the threat-variable correlation is negative. For example, droughts have a negative correlation with precipitation (i.e., the higher the future precipitation, the lower the drought severity).
- 2. Decreasing severity:
  - If the trend of the primary variable is decreasing and the threat-variable correlation is positive.

- If the trend of the primary variable is increasing and the threat-variable correlation is negative.

➢ 3. Stable:
If the primary variable demonstrates insignificant variation (within the timeframe of the assessment).

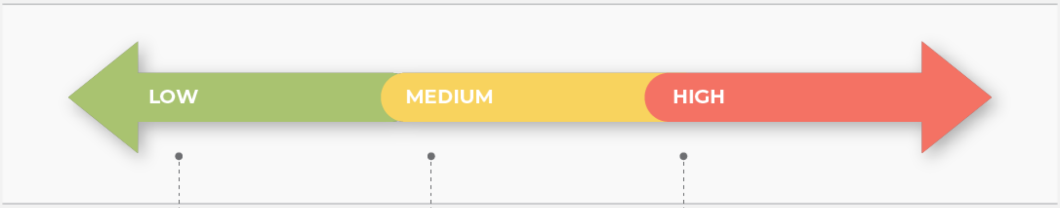
Users are requested to observe the global (and, if available, regional) future projections of the corresponding primary variable and make reasonable guesses about the future trend of the threat under consideration. For example, if the project region is showing an increasing trend in average precipitation (and if no other data are available), it is reasonable to anticipate an increase in extreme rainfall and flood events.

It is generally considered a good practice to use different climatic projections representing different Representative Concentration Pathway (RCP) scenarios.

6 **Assess the future threat level** (applies both for acute hazards and chronic threats)

For acute hazards: assess the future hazard level by combining current hazard intensity and future trends. For example: for a "medium" current hazard level with an "increasing" trend, the future hazard level will be set to "high."

For chronic threats: use the scoring system provided below to rate the severity of the threat based on the rate of anticipated change of the primary stressor. Information on the evolution of the primary variable for different climate scenarios may be directly retrieved from publicly available GCMs. Users may also refer to the resources of **Table 3.1,** which contains aggregated data from a variety of GCMs.



LOW	MEDIUM	HIGH
No significant change (with respect to present values within the timeframe of the assessment).	Notable change over a time period exceeding the timeframe of the assessment (e.g., more than 50 years).	A significant change is expected within the timeframe of the assessment (i.e., in the case of a rapidly evolving phenomenon).

OUTPUT

A preliminary characterization of the climate hazards/stressors potentially affecting the project for current and future climate conditions.

APPLICATION EXAMPLE - Part A

Case: Consider a fictitious water facility that abstracts water from groundwater aquifers and conveys it to a central reservoir connected to the regional distribution network. The water from the facility will be used for both agricultural irrigation and domestic use. The facility is located in a region that is expected to experience droughts in the years to come.

Question: The public authority wants to know the expected severity of droughts according to different climate scenarios.

Rationale: Drought is a chronic condition rather than an acute threat. It is associated with two climate variables, temperature and precipitation (reading from **Table 3.2**). Drought conditions are exacerbated when temperatures are rising while precipitation is decreasing. The climate projections at the location of interest for the two climatic variables considering two different climate scenarios (RCP 4.5 and RCP 8.5) are summarized below (information retrieved from the Climate Change Knowledge Portal; see **Table 3.1**).

	Annual average temperature	Mean annual precipitation
RCP 4.5	Increase of 1 to 1.5 °C compared to the present-day climatology	Change: -2% to +2%
RCP 8.5	Increase of 2 to 5 °C compared to the present-day climatology	Change: -10% to +1%

Notably, according to the RCP 4.5 scenario, the present climate conditions will not change substantially (neither in terms of temperature nor in terms of rainfall). Yet the more pessimistic RCP 8.5 scenario predicts increased temperatures and reduced precipitation that in combination may trigger drought conditions.

Answer: In summary, the drought hazard can be classified as follows:

	Drought Hazard
RCP 4.5	Low
RCP 8.5	Medium – High

IMPORTANT NOTE

Future Climate Projections RCPs and SSPs

It is common practice to project future climate conditions based on the Representative Concentration Pathways (RCPs) to represent different trajectories of radiative forcing levels over time. Out of the four RCP scenarios, RCP 8.5 represents the highest emissions scenario, whereas RCP 2.6 represents the lowest emissions scenario. RCP 2.6 should generally be avoided when making projections because it is overly optimistic compared to recent emissions trends.

In 2016, the Shared Socioeconomic Pathways (SSPs) were introduced as an update and a substantial expansion over the RCPs. The SSP framework contains a total of eight different climate trajectories based on alternative/plausible scenarios of future emissions and land-use changes, by which society and ecosystems will evolve in the 21st century. Global scale predictions of climate parameters for different SSPs are available in the WorldClim database.

TABLE 3.1 List of resources that can be used for preliminary identification of climate hazards at the project location

Resource	Description	Climate Scenarios	Link
World Bank Climate and Disaster Risk Screening Tools developed by the World Bank Group	The World Bank's Climate and Disaster Risk Screening Tools represent a proactive approach to considering short- and long-term climate and disaster risks in project and national/sector planning processes. There are two levels of screening: a rapid, cursory assessment of current and future climate risks, and a more in-depth assessment that produces a more detailed project risk report. Additional resources (related to the water sector) that provide information on climate data, climate-change impacts and adaptation, and other useful information that can help to better understand climate and disaster risks to national- or project-level activities are also provided.	**Yes**	https://climatescreeningtools.worldbank.org
Climate Change Knowledge Portal (CCKP) developed by the World Bank Group	The CCKP contains climate, disaster risk, and socioeconomic datasets, as well as synthesis products, such as the Climate Risk Country Profiles, that include climate-related natural hazards and climate change impacts. Temperature-related variables (e.g., number of hot/frost days, mean temperature) and precipitation-related variables (e.g., average largest five-day cumulative rainfall) are available historically and for future projections based on different climatic models.	**Yes**	https://climateknowledgeportal.worldbank.org
ThinkHazard! developed by the World Bank Group	ThinkHazard! provides a general view of the hazards (river flood, earthquake, drought, cyclone, coastal flood, tsunami, volcano, and landslide) for a given location. The tool highlights the likelihood (rated very low, low, medium, and high) of different natural hazards affecting project areas; provides guidance on how to reduce the impact of these hazards; and indicates where to find more information. A brief statement is made to describe the potential impact of climate change on the hazard.	**Yes**	https://thinkhazard.org
ClimateLinks developed by the US Agency for International Development (USAID)	ClimateLinks is a global knowledge portal that includes climate-related information and tools. Regional and country risk profiles are available, providing key climate stressors and risks for different regions or countries. Climate projections include temperature, precipitation variability, extreme weather events, and sea level rise.	**Yes**	https://www.climatelinks.org/climate-risk-management/regional-country-risk-profiles

Resource	Description	Climate Scenarios	Link
Intergovernmental Panel on Climate Change Working Group I (IPCC WGI) Interactive Atlas developed by the IPCC	The Interactive Atlas regional information supports the assessment done in the Sixth Assessment Report (AR6) WGI chapters, the Technical Summary and the Summary for Policymakers, allowing for flexible temporal and spatial analyses of trends and changes in key atmospheric and oceanic variables, extreme indexes and climatic impact drivers related to temperature, sea level rise, sea ice concentration, drought, wind and storm, snow/ice, and more.	**Yes**	https://interactive-atlas.ipcc.ch/
WorldClim developed by WordClim	Contains historical climate data (temperature, precipitation, wind speed, water vapor pressure) and a spectrum of future weather maps (temperature and precipitation) with a 30-second spatial resolution.	**Yes**	https://www.worldclim.org/
Aqueduct developed by the World Resources Institute	Aqueduct's tools (including the Aqueduct Water Risk Atlas and the Aqueduct Floods) use open-source, peer reviewed data to map water risks such as floods, droughts and stress.	**Yes**	https://www.wri.org/aqueduct
WESR-Risk developed by the United Nations Environment Programme/Global Resource Information Database Geneva (UNEP/GRID-Geneva)	This platform provides access to global datasets regarding hazards (floods, droughts, forest fires, tropical cyclones, earthquakes, tsunamis, landslides, volcanoes), the exposure (economic or population), as well as the risk of losses (mortality and economic risk).	**No**	https://wesr.unepgrid.ch/?project=MX-XVK-HPH-OGN-HVE-GGN&language=en

TOOL 3.2

ASSESSMENT OF CLIMATE IMPACTS

Climate impacts on water utilities can materialize in the form of:

- Water shortages due to decreased water supply
- Increased operating expenses (e.g., due to deterioration of water quality, requiring more advanced treatment)
- Physical damages to critical components of the water facility, causing increased maintenance/replacement costs and business disruption
- Operational disruptions caused by loss of service at an interconnected facility (e.g., loss of power)
- Indirect impacts (e.g., contamination of reservoirs following flood events or saltwater intrusion into the aquifers due to extensive pumping).

In all cases, impacts introduce economic loss which is reflected in increased expenditure, operational cost or revenue loss. The higher the expected loss, the higher the severity of the impact.

INPUT

The tool assists users in qualitatively assessing the impact[32] of the climatic threats identified above (input from **Tool 3.1**) on the water project (and the project components).

1 **Think of the different ways the water facility can be impacted by climate change**

For each hazard entry included in the hazard matrix of **Tool 3.1**, use the information provided in **Table 3.2** to describe the climate-related impacts to the facility. Whenever possible, highlight critically vulnerable elements (i.e., impacted components/processes that are essential for the operation of the facility). For example, damage to an air compressor caused by a flood event will limit the operation of pneumatic valves on the treatment process systems, rendering the facility inoperable. Having a clear understanding of the spectrum of climate-related impacts on the facility will allow users to devise adaptation strategies that precisely address its critical vulnerabilities. Further guidance on the potential impacts on water production and treatment infrastructure components may be found in Appendix 1 of the World Bank's "Resilient Water Infrastructure Design Brief."[33]

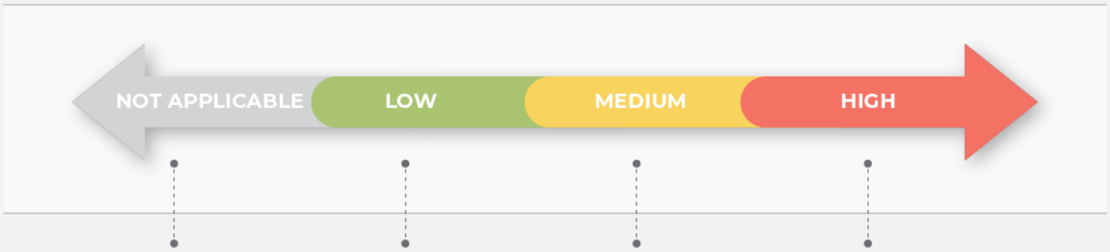
[32] This tool focuses on potential negative impacts for which adaptation measures should be planned. However, sometimes climate stressors can positively impact the facility (i.e., increased precipitation will increase the groundwater recharge and hence the supply capacity of the project—provided that the infrastructure of the facility can sustain the additional abstraction requirements). For the purposes of this preliminary assessment, positive impacts have been tacitly excluded from consideration.

[33] World Bank. 2020. "Resilient Water Infrastructure Design Brief." Working Paper. https://openknowledge.worldbank.org/handle/10986/34448.

2 **Assess the potential loss** associated with negative impacts. Assessments should include:

1. Number of days per year that the facility is out of service (e.g., due to damage to critical asset components or operational disruption)
2. Expected reduction in water production
3. Cost of repairs (e.g., for replacing damaged or malfunctioning equipment)
4. Increases in operational cost (e.g., due to increased energy needs).

3 **Appraise impact severity**: Use the qualitative scale provided below to characterize the criticality of each potential impact on the operability and water production capacity of the facility.



NOT APPLICABLE	LOW	MEDIUM	HIGH
The project is not impacted by the climate threat.	▪ Components of the facility may be slightly damaged. ▪ Damaged components can be restored quickly and at low cost. ▪ The facility may operate at reduced capacity for a few hours.	▪ Substantial parts of the facility may be moderately damaged. ▪ Damage/service restoration can be costly. ▪ Operational disruptions may last for a few days.	▪ The majority of the facility has been severely damaged, requiring extensive restoration or replacement activities. ▪ The facility may remain out of service (or operate at reduced capacity) for an undetermined period. ▪ Unreliable service and social distrust.

OUTPUT

A comprehensive listing of potential climate impacts on the project and the project's components highlighting key system vulnerabilities.

BOX 3.2 FLOODING CAN LEAD TO WATER CRISIS

August 2022, Jackson, Mississippi, United States: An ongoing water crisis in and around the city of Jackson, Mississippi, began in late August 2022 when torrential rain coupled with existing infrastructure problems cut off access to clean drinking water for most of the city's residents. The main water treatment facility for the city of Jackson, the O.B. Curtis Water Plant, failed, leaving residents with little to no reliably clean drinking or running water due to possible contamination and lack of pressure for days.

February 2017, Santiago, Chile: Rainstorms and landslides triggered by rainfall in Santiago, Chile, contaminated the Maipo River, forcing officials to cut off drinking water for 4 million people. Two days after the event, the main plant, the Las Vizcachas water treatment plant, resumed operation, and roughly 50 percent of the homes in Santiago regained access to potable water. In addition to the main plant, alternative supply points were set up by the company until service was fully restored.

TOOL 3.3
ASSESSMENT OF CLIMATE RISKS

Following the definitions provided in the Umbrella Toolkit (Modules 1.2 and 2.1), internal climate risks originate from hazards/stressors that are posed directly on the project and describe the **likelihood of the project to experience an impact of a given severity**. In preliminary climate assessments, the term likelihood is schematically used to encapsulate two factors:

5. The frequency of the climate event (i.e., how often does the facility experience such impacts). In general, the frequency of the event can be directly correlated to its intensity: the stronger the event, the lower its frequency.
6. The uncertainty of the evolution of climatic factors.[34]

INPUT

The tool may be used for a qualitative assessment of internal climate-induced risks for water projects. **Tool 3.3** will be used in combination with **Tool 3.4** (where external risks originating from hazards affecting not the project per se but its broader socioeconomic system are assessed) to estimate the total (internal and external) climate risk of the water project.

[34] In that respect, climate projections associated with the (very pessimistic) RCP 8.5 scenario may be considered less probable to materialize than those associated with an RCP 6.0 or RCP 4.5.

1 **Assign likelihoods to hazards/stressors** potentially affecting the project.

For acute hazards: As a rule of thumb, set likelihood to “low” for events that take place once or twice in the life cycle of the project (e.g., an extreme flood that may cause inundation of the entire facility), and “high” for events that happen every one to five years.

For chronic stressors: For conservative estimates, consider setting the likelihood to “high” for all climate projections. Alternatively, set the likelihood equal to “low-medium” for climate projections made under RCP 8.5, and assign “high” likelihood to climate projections that are consistent with an RCP 4.5 or 6.0.

Note: Before setting probabilities to RCPs, it is recommended to consult national adaptation documents to guarantee compliance with the prescribed risk assessment framework.

2 **Calculate the climate risk level of each hazard/stressor** according to the equation [HAZARD x LIKELIHOOD] x IMPACT using the two-dimensional color matrix provided below.

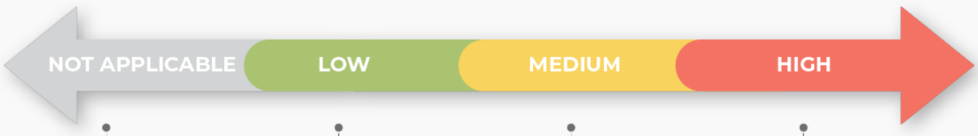
First, combine HAZARD/STRESSOR with LIKELIHOOD to estimate THREAT severity. Then combine THREAT severity with IMPACT severity to calculate RISK level (i.e., read hazard severity in the first column and combine it with the IMPACT score displayed in the first row).

Example calculation: [Low x Medium] x High = Low x High = Medium

	Low	Medium	High
Low	LOW	LOW	MEDIUM
Medium	LOW	MEDIUM	HIGH
High	MEDIUM	HIGH	HIGH

3 **Build the risk matrix of the project** combining risks stemming from all potential threats and considering climate scenarios.

4 **Describe consequences and, where possible, provide cost estimates for the level of operational disruption**. As displayed in the graphic below, low climate risks are associated with minimum disruptions to the facility and the broader community, whereas high climate risks may cause service unavailability for several days and significant revenue loss (that can be catastrophic for the investment). In extreme cases, a prolonged water crisis can create social outrage and distrust.



NOT APPLICABLE

Minor operations disruptions are very rare.

LOW

- The facility may experience (e.g., once per year) minor operational disruptions.
- Major operational disruptions are very rare.
- The increase in maintenance cost is relatively low.
- The energy production of the facility will remain constant (even for the RCP 8.5 projections).

MEDIUM

- Significant operational disruptions may happen on an annual basis or less frequently.
- A moderate increase in the maintenance cost should be expected.
- A slight decrease of energy production for RCP 6.0 or 4.5 projections (and a moderate decrease for the RCP 8.5 projections).

HIGH

- Major operational disruptions may take place frequently.
- Maintenance cost may substantially increase.
- A considerable decrease in energy production is projected in all RCP scenarios.

OUTPUT

A systematic description of all potential climate risks affecting water facility project and associated rough cost estimates.

TABLE 3.2 Climate-change threats and their potential impacts on **water facilities**

Climate Threats	Primary Variable (correlation)	Impacts
CHRONIC CLIMATE THREATS		
Droughts	Temperature (positive correlation) Precipitation (negative correlation)	• Reduced water levels in aquifers and reservoirs will impact the water production capacity of facilities that primarily rely on groundwater supplies. • Increased pumping demands may trigger sea water intrusion in coastal aquifers or intensify such a problem if it exists already. • Reduced water surface flows will impact facilities relying on surface water supplies. • Difficulty meeting water demands, especially in the summer months. • Accelerated snowpack decline will strain the capacity of reservoirs to hold larger and earlier peak runoff flows, causing shortages in the summer due to the longer duration of the warmer and drier season.
Lower precipitation	Precipitation (positive correlation)	• Lower streamflow may lead to diminished water quality, requiring advanced treatment that increases operational cost.
Salt water intrusion into aquifers	Sea-level rise (positive)	• Diminished water quality will increase water treatment cost for facilities drawing water from aquifers or surface water intakes that are near the saltwater line. • Desalination plants will have to treat water with higher salt content, which will increase operational costs.
Degraded water conditions	Temperature (positive correlation) Precipitation (negative)	• Algal growth increase in low-flow areas will compromise water quality. • Advanced treatment processes for drinking water may apply, requiring higher energy demands and increased capital and operating costs.
Soil erosion	Precipitation (positive)	• Turbidity from sediment washing (following storm events) will diminish quality of receiving water, leading to higher treatment cost, and need for capital improvements. • Reduced inflows will increase infiltration cost for contaminant removal.

Climate Threats	Primary Variable (correlation)	Impacts
CLIMATE HAZARDS		
Flooding and coastal storm surges	Precipitation (positive) Sea level rise (positive)	• Inundation of treatment plants, intake facilities, water conveyance and distribution systems will cause damage to pumps, pipelines, and other electromechanical equipment. • Increased maintenance costs for repairs and replacements. • Disruption of water service due to damage to critical assets/components. • Episodic peak flows into reservoirs may strain the system.
Extreme heat	Temperature (positive)	• Increased water demands on very hot days will strain the daily outflow capacity of the facility.
Fires	Temperature (positive)	• Physical damage to water facility infrastructure. • Runoff and flash floods from burned areas will increase sedimentation in reservoirs, hence reducing their capacity and service lifespan. • Increased pollutant loads in reservoirs will accelerate algal growth, which may require higher treatment costs.
Tropical storms	Precipitation (positive)	• Physical damage to water facility infrastructure. • Increased maintenance cost for repairs and replacements. • Disruption of water service due to damage to critical assets/components.
Landslides and mudflows	Precipitation (positive)	• Debris flow can threaten the quality of water. • Water contamination may lead to service disruption until drinking water quality is restored. • Physical damage to conveyance pipelines.

APPLICATION EXAMPLE - Part B

Question: How will the projected drought conditions impact the facility?

Rationale: Reverting to the hazard mapping exercise of the example case, let's recall that the intensity of the drought differs between the two climate scenarios. The impacts on the facility are analogous to the severity of the drought and can be summarized as follows:

	Drought Impacts on the Ecosystem	Impacts on the Facility
RCP 4.5	▪ No substantial change in the level of water reservoirs ▪ Moderate increase in seasonal demands during hot summer months and increased peak daily demands during very hot days	Operational disruption: LOW ▪ 95 percent operability for two to five days per year ▪ 100 percent operability for the remaining days Revenue Loss: LOW 1 to 2 percent loss compared to normal operational conditions Public acceptance: HIGH Nothing to comment
Severity of the impact		**LOW**
RCP 8.5	▪ Reservoir level is critically low ▪ Available water resources cannot cover household and agricultural needs	Operational disruption: HIGH ▪ Low water pressure during high demand hours ▪ Decreased average water outflows by an order of 15 percent Revenue Loss: HIGH ▪ 10 percent decrease in revenues due to reduced water consumption ▪ Facility owner may be subject to penalties for providing low water quality Public acceptance: LOW Frequent disruptions and water competing issues negatively impact public opinion.
Severity of the impact		**HIGH**

Answer: Combined hazard and impact severity of the facility's drought risk is summarized as follows:

	Drought risk
RCP 4.5	LOW
RCP 8.5	HIGH

TOOL 3.4

EVALUATION OF CLIMATE-CHANGE-INDUCED EXTERNALITIES AND IMPACTS

External risks originate from hazards/stressors affecting either the interlinked infrastructure of the water facility or its broader socioeconomic system, thus indirectly impacting the project's operations and water production capacity. Because external risks are beyond the control of the project, it is important to identify them early in the project selection process, estimate the severity of their impacts, and plan ahead for ways to alleviate their consequences. It may be advisable to restructure or even abandon projects that experience high external risks which cannot be mitigated.

Although the focus of this guide is on climate-induced risks, transition risks and other externalities nonetheless remain critical for the planning of new water projects. These may include changes in demographics (which can be further complicated due to altering regional migration patterns due to climate change) or changes in the energy supply (i.e., changes in energy pricing and availability).

INPUT

This tool may be used to perform a preliminary screening of climate and non-climate externalities that potentially strain the availability and operations of the water facility.

1

Identify external risks that are pertinent to the regional setting of the water facility under consideration.
A list of commonly encountered external risks in water projects is provided in **Table 3.3**. The listing is indicative, describing conditions that may introduce positive or negative externalities to the project. The users are requested to customize the list as appropriate to make it relevant to the project specifics.
For each table entry, conditions—where climate change could act as a multiplier on the economic and social pressures of the project—are specifically described.

2

Score the external risk level as "low," "medium," or "high" (specifying risk sources that are particular to the project under consideration) and add results to the risk matrix of the project (output of **Tool 3.3**).

3

For each externality, estimate potential losses (or gains) and think of ways to remediate their negative consequences. Although in principle external risks lie outside the responsibility of the facility owner, unmitigated risks can negatively impact investor appetite and the bankability of the project. Users should make sure due diligence is practiced when assessing the project's climate externalities.

Note: Mitigation of external risks is rarely solved through better (or more expensive) adaptation plans. Such mitigation commonly requires the structuring of adequate risk allocation clauses that specifically describe the responsibility boundaries of the facility owner and provide for the compensation/negotiation mechanics to manage losses. It may also require the addition of contractual provisions that specify strategies/plans to be implemented in parallel with the water project (e.g., water

conservation practices in facilities and households) to reduce its risk to external factors.
It is therefore recommended to revisit and re-evaluate external risks in Phases 2 and 3 of the PPP project cycle, when the bankability of the project is appraised in greater detail and the risk allocation and contract documentation are structured.

TABLE 3.3 External risks and consequences for water projects

External Factors/Climate Change Multipliers	Example Consequences
Demographic changes in the characteristics of human population and alterations in regional migration patterns due to climate change	Population size, number of households, urbanization, and economic development influence demographics and hence the amount of water withdrawn and the quality of the water available. Climate change is considered both a direct and an indirect driver of migration that complicates existing demographic projections, especially in agriculturally dependent communities. People migrate from one location to another or migrate to cities to protect from drought, fluctuating temperatures, and unpredictable rainfall that reduces crop yields.
Agricultural production and changes in agricultural practices in response to climate change	Agricultural production is expected to increase to meet the population growth and the increasing demand for food. As a result, the water demand for agriculture (which traditionally accounts for 70 percent of freshwater withdrawals globally) will increase, and so will competition for water resources. Climate change is expected to modify agricultural practices and hence water requirements. Farm operators change production practices and land use to increase the carbon stored in soil or vegetation and produce biofuels. Irrigation practices are modernized to diminish water loss and increase efficiency. Such changes may significantly alter the water use patterns impacting the ability of drinking water utilities to provide sufficient supply for their ratepayers.
Energy needs and changes in energy pricing due to climate change	The water sector requires energy to operate, and the energy sector relies on water resources to produce energy (e.g., through thermoelectric power generation, hydropower). Water scarcity (exacerbated by climate change) will affect the availability and pricing of energy. Moreover, energy blackouts may become more frequent in response to increased demands during extreme weather events, with cascading effects for the operation of the water facility.
Land use/land cover (LULC) changes, which can be exacerbated by climate change (e.g., changes in agricultural land use, or changes in vegetation and snowpack)	LULC changes can modify streamflows and groundwater resources impacting the ability of water utilities to provide sufficient supply for their clients. Moreover shifts toward water-depleting modes of agriculture (e.g., farmers shifting from their customary crops to crops that will have higher economic return under changing climatic

	conditions) will increase water competition and will strain the ability of the water facility to keep up with the increased demands.
Disruptive technologies and climate-change-driven innovations	Technology can positively impact the operations of water facilities in many ways. Although the use of the internet of things is not mainstreamed, it has many potential advantages that are not yet completely understood. Increased energy efficiency through smart metering of energy usage, reduced leakage, and application of preventive maintenance approaches can disrupt water operations, allowing for reduced operational expenditures (OPEX) and enhanced water conservation. Climate change can also drive technologic innovations toward: 7. Climate mitigation, where the advances in renewable energy technology can decrease the dependence of the water facility on the external grid and substantially reduce the cost of energy. 8. Climate resilience, where modern weather forecasting tools and rapid response platforms are exploited to prevent the risk of catastrophic failure.
Barriers to the supply and transfer of bulk water	Climate change modifies streamflows and groundwater resources and hence the water production capacity of reservoirs. Facilities that rely on bulk water transportation may find themselves at a disadvantage if the water level of their supply reservoirs decreases below certain thresholds.
Policy changes including regulations for sustainability and climate change	As global awareness of climate change is rising, new climate policies and guidelines are emerging and will continue to emerge in the years to come. Within this constantly evolving regulatory framework, the application of green infrastructure solutions is growing, green incentives are promoting sustainable developments, environmental requirements are becoming more stringent, and polluters are being subjected to higher fees. All of the above have direct implications for the CAPEX and operating expenses (OPEX) of the facility, and may positively or negatively impact the profitability of the investment.

OUTPUT

A ranked list of climate externalities for the project, including a description of consequences and possible remediation measures.

Step 2

Screen And Appraise Adaptation Strategies

SCOPE	To provide examples of different actions (i.e., adaptation options) the utilities can take to prevent the impacts of climate change and safeguard operations and missions while maximizing the positive socio-environmental impact of the project.
PROCESS	The process starts with a detailed mapping of possible adaptation solutions addressing the project's climate risks (derived from **Tool 1.3**). Special reference is made to adaptation solutions that not only contribute to climate resilience but that also offer opportunities for sustainable water management and energy efficiency. Users are then asked to build alternative adaptation strategies combining different adaptation measures. The alternative strategies may differ in terms of capital costs and may offer varied forms of protection within the multi-hazard environment of the project.
	
TOOLS	**TOOL 3.5** Building climate adaptation strategies **TOOL 3.6** Planning of climate adaptation strategies
OUTPUT	Adaptation strategies that are appropriate for the level of risk to which the facility is exposed.

TOOL 3.5

BUILDING CLIMATE ADAPTATION STRATEGIES

The adaptation strategies for water supply systems can be classified into three major groups:

- **Planning strategies** intervene in the supply and demand of the facility, improve natural resource management, and establish water-management collaborations. Examples may include diversification of supply sources, investigating water system interties, and engaging customers in extensive conservation efforts. In principle, planning strategies tend to be less costly than operational and capital strategies and are therefore regarded as low-regret options.
- **Operational strategies** aim to improve the efficiency of the facility, thus reducing operational and maintenance costs. Such strategies can be accomplished through systematic monitoring (e.g., monitoring groundwater conditions to inform aquifer management), emergency response plans providing resilience, and proactive maintenance to increase the lifetime of the equipment and prevent episodic malfunctions during acute climate events.
- **Hard-engineering solutions** aim to augment or optimize the capacity of the facility to better absorb climate impacts. These interventions typically involve a higher level of capital investment and may include: expansions in the original planning (e.g., building a new dam to increase water supply or increase the capacity of the collection system); repairs and/or rehabilitation works to individual assets; construction of risk protection measures (e.g., seawalls to prevent inundation and saltwater intrusion); or equipment replacement (e.g., higher capacity pumping systems for increased water production). In this category, one may also find nature-based solutions (NbS) that work with natural processes to reduce risks (e.g., manage stormwater runoffs using bio-retention areas/swales or through restoration of vegetated land cover in watersheds).

INPUT

This tool will guide users through the process of structuring climate adaptation strategies that are appropriate for the level of anticipated climate risk, the resources available, and the public authority's priorities.

1 **Select adaptation measures**.
Focus on the threats that, based on the preceding analysis, introduce medium-high risk to the water project. For those threats, look up the examples of **Table 3.4** and catalogue options that can be applicable to the project under consideration. Note that adaptation measures can be devised for both internal and external risks.

2 **Build adaptation strategies combining different adaptation options**.
For best results, combine planning, operational and hard-engineering practices. It is also recommended to prioritize practices that have been successfully applied in projects of similar scale (in similar regional settings).

Adaptation strategies may be characterized by different failure thresholds and can offer different levels of protection across climate scenarios. For example, an operational strategy coupled with minimal engineering works may be enough to absorb small changes in the climatic variables, but hard-engineering solutions will be required to cope with the most pessimistic climate projections.

3 **Review adaptation strategies and generate alternatives** by including adaptation options that offer combined sustainability/resilience benefits.

Many sustainable practices offer opportunities to address climate change risks in a socially, economically, and environmentally responsible way. For ease of reference, these options have been marked with an icon ( ).

4 **Roughly estimate cost/benefit estimates for each adaptation strategy.**
Cost estimates should aggregate the capital expenditure required for the implementation of the strategy and the cost of residual risk projected over the lifetime of the facility. Benefits should describe the reduced maintenance/operational cost of the facility after the implementation of the strategy (projected over the facility's lifetime). Where possible, apply benchmarking to validate cost estimates. When benchmarking does not work (e.g., when historic market data are not enough), apply small-scale market testing to corroborate cost estimates.

5 **Repeat** the process for other climate hazards to come up with a complete strategy for the project.

OUTPUT

A list of alternative adaptation strategies that will be passed on to the following step for a threshold analysis.

BOX 3.3 A NATURE-BASED SOLUTION FOR ADDRESSING CLIMATE RISKS IN WATER FACILITIES

Situated in the population-dense, water-scarce, and wildfire-prone area of São Paulo, Brazil, **Saneamento Básico do Estado de São Paulo** (SABESP) faces increasing pressure to supply sufficient and good-quality water to its 26.7 million customers. Characteristic of the urgency of the situation is that, in 2015, southeast Brazil experienced its worst drought in nearly a century.

To protect and restore its catchment areas from degradation, SABESP designed a nature-based solution program that prioritizes reforestation and engages water users in coordinated conservation efforts across the watersheds it depends on. The program pursued the preservation of 33,000 hectares of land around four watersheds. The implementation of the NbS plan experienced some setbacks, first and foremost the increased risk of wildfires, which was exacerbated by the prolonged drought in the region.

Source: The Nature Conservancy and the International Water Association. 2019. *Nature for Water: A Series of Utility Spotlights*.

TABLE 3.4 Example climate adaptation measures for water projects. Sustainability practices are marked with this icon:

Climate Threats	Impacts	Adaptation Measures
INTERNAL RISKS		
Drought	• Reduced water levels in aquifers, reservoirs, and surface flows impact the water production capacity of facilities • Difficulty meeting water demands, especially in the summer months • Accelerated snowpack decline will strain the capacity of reservoirs to hold larger and earlier peak runoff flows • Shortages in the summer due to longer duration of the warmer and drier season	**Build infrastructure for aquifer storage and recovery** (to enable recharge when surface water flows exceed demand, hence increasing resilience during drought periods). Depending on whether natural or artificial aquifer recharge is employed, the required infrastructure may include percolation basins or injection wells. **Diversify options for water supply to prevent water scarcity** (i.e., when water supply falls below water demand): **9.** Mixing surface water and groundwater **10.** Employing desalination **11.** Establishing water trading (with other utilities) and water reuse/recycling schemes to cope with water shortages and prevent service disruptions. **Increase water storage capacity by:** 12. Building dams 13. Removing sedimentation in reservoirs 14. Lowering water intake elevation. **Establish mutual aid agreements with neighboring utilities** **15.** Water trading in times of water shortage **16.** Sharing of resources during emergencies. **Prepare drought contingency plans** and include relevant provisions in the contract documentation of the PPP. The plan will describe: **17.** Use of alternate water supplies **18.** Water usage restrictions in times of drought.

Climate Threats	Impacts	Adaptation Measures
		Prepare water conservation plans and include provisions in the contract documentation of the PPP. The plan will describe: 19. Water metering practices 20. Time of day to undertake water-intensive activities 21. Ways to promote the use of water-efficient household appliances such as low-flow toilets, showerheads and front-loading washers 22. Implementation of rain harvesting 23. Water conservation technologies (e.g., micro-irrigation technologies to limit agricultural demand).
Lower precipitation	• Lower streamflows diminish water quality • Advanced treatment requirements increase operational cost	**Increase treatment standards of facilities** to be able to process water of reduced quality. **Retrofit intakes** to accommodate lower flow levels. **Invest in off-grid sources** or use on-site renewable energy restoration to reduce energy demand and control operational cost.
Salt water intrusion	• Increased water treatment cost for facilities drawing water from aquifers or surface water intakes that are near the saltwater line • Increase operational cost for desalination plants	**Install low-head dams** across tidal estuaries to prevent saltwater intrusion. **Inject fresh water into aquifers** to prevent saltwater intrusion. **Practice aquifer management** to monitor and control saltwater intrusion.
Degraded water conditions	• Algal growth increase in low flow area compromising water quality • Advanced treatment processes are applied requiring higher energy demands and increased capital and operating costs	**Manage water quality** by combining watershed management, groundwater recharge, and reservoir management methods (e.g., lake aeration).

Climate Threats	Impacts	Adaptation Measures
Soil erosion	• Turbidity from sediment washing (following storm events) diminish water quality • Higher treatment cost and need for capital improvements • Reduced inflows decrease water production capacity • Increased infiltration cost for contaminant removal	**Acquire and manage ecosystems** to reduce sediment and nutrient inputs into source water bodies to regulate runoff and increase protection against coastal flooding. **Preserve or restore vegetated land covers in watersheds** to manage stormwater runoff and reduce soil erosion. **Monitor critical components** to detect signs of deterioration early (e.g., increased sedimentation).
Flooding and coastal storm surges	• Inundation of treatment plants, intake facilities, water conveyance and distribution systems • Damage to pumps, pipelines, and other electromechanical equipment • Increased maintenance costs for repairs and replacements • Disruption of water service due to damage to critical assets/components • Episodic peak flows into reservoirs may strain the system capacity	**Consider future flood risk maps** when building water infrastructure. Apply stringent design considerations for critical assets. **Build flood defenses** (e.g., seawalls and dikes). **Acquire and manage ecosystems** to reduce sediment and nutrient inputs into source water bodies, regulate runoff and increase protection against coastal flooding. **Restore mangroves** and wetlands to enhance coastal flood resilience.
Extreme heat	• Increased water demands on very hot days will strain the daily outflow capacity of the facility	**Install effluent cooling systems** to reduce treatment temperatures.
Fires	• Physical damages to water infrastructure • Runoff and flash floods from burned areas increase sedimentation in reservoirs, reducing capacity and service lifespan • Increased pollutant loads in reservoirs accelerate algal growth leading to higher treatment cost	**Develop fire models and set provisions for fire management plans** (e.g., controlled burning).

Climate Threats	Impacts	Adaptation Measures
Tropical storms	• Physical damages to water infrastructure • Increased maintenance cost for repairs and replacements • Disruption of water service due to damage to critical assets/components	**Consider future flood risk maps** when building water infrastructure. Apply stringent design considerations for critical assets. **Build flood defenses** (e.g., seawalls and dikes). **Acquire and manage ecosystems** to increase protection against coastal flooding.
Landslides and mudflows	• Debris flow can threaten the environmental quality of water • Water contamination may lead to service disruption until water drinking quality is restored • Physical damages to conveyance pipelines	**Diversify options for water supply** to increase the redundancies of the water facility. **Apply modern water contamination monitoring methods** that issue automatic alerts when contaminants exceed maximum thresholds and reduce the response time of the facility in case of emergency. **Design piping systems to withstand large ground deformations** (e.g., thicker pipelines, increased embedment depth), add redundancies by duplicating critical components, incorporate reroute plans.
EXTERNAL RISKS		
Demographic and LULC changes (including changes in agricultural production)	• Modified streamflows and changes in groundwater resources • Annual changes and seasonal volatility in water use patterns and water demand • Possible deterioration of water quality	**Diversify options for water supply** to increase the redundancies of the water facility. **Increase treatment standards of facilities** to be able to process water of reduced quality. **Prepare water conservation** plans and include provisions in the contract documentation of the PPP. The plan will describe: 24. Water metering practices 25. Time of day to undertake water-intensive activities 26. Ways to promote the use of water-efficient household appliances such as low-flow toilets, showerheads, and front-loading washers

Climate Threats	Impacts	Adaptation Measures
		27. Implementation of rain harvesting 28. Water conservation technologies (e.g., micro-irrigation technologies to limit agricultural demand).
Increased energy needs	29. More frequent energy blackouts during periods of increased energy demand (e.g., during extremely hot or cold days) 30. Increased energy bills negatively impact revenues 31. Volatility in energy pricing hinders planning actions	**Energy efficiency measures** will save on energy costs and make utilities less vulnerable to electricity shortfalls due to high demand or service disruptions from natural disasters. **Plan and establish alternative or on-site power supply** to prepare for energy shortages (that may become more frequent because future electricity demand is forecasted to grow). Use on-site renewable energy generation to lower energy consumption.
Barriers in the supply and delivery of bulk water		**Diversify options for water supply** to increase the redundancies of the water facility. **Establish mutual aid agreements with neighboring utilities** **32.** Water trading in times of water shortage **33.** Sharing of resources during emergencies.

TOOL 3.6

THRESHOLD-BASED APPRAISAL OF ADAPTATION STRATEGIES

Because of the great deal of uncertainty surrounding the timing, nature, direction, and magnitude of climate impacts, it remains challenging to make long-term adaptation decisions that will meet future needs without risking overdesigning. Decision-making under uncertainty methodologies offer the mathematical framework for conducting such assessments. (An example application is presented in **Box 3.4.**) Despite their rigor, these approaches require a great deal of resources and expertise to which public authorities do not have access during the initial stages of PPP preparation.

In such a context, this tool describes a simplified threshold-based approach that can be used for a very preliminary appraisal of adaptation strategies. Following a multi-tiered rationale, the users disqualify options that do not meet minimum planning requirements and select among competing alternatives the one that is more cost efficient and offers adequate protection over a range of plausible futures.

INPUT

1 **Select candidate adaptation strategies for appraisal.**

Retrieve the list of adaptation strategies from **Tool 1.5**. If multiple adaptation strategies have been selected, try reducing the number of candidates by eliminating similar alternatives (i.e., alternatives that apply similar methods and have similar implementation budgets). This will save time and resources during the next steps of the assessment.

2 **Determine thresholds** for each adaptation strategy.

When compared to projected futures, thresholds represent the capacity of the adaptation strategy to serve its purpose. When threshold conditions are exceeded, the mission of the facility and the profitability of the investment will be at stake.

Although thresholds should in principle be determined through modeling of the system's performance, for the sake of this preliminary analysis, an evidence-based derivation of thresholds is considered appropriate.

Users are therefore encouraged to study past events and the performance history data of similar facilities, and consult facility operators to decide on the threshold conditions that best describe the capacities of their facility (and the adaptation strategy).

3 **Define the benchmark and eliminate below-threshold strategies.**

Benchmarks should encapsulate the minimum planning objectives pursued through adaptation planning. Hence, adaptation solutions that do not meet the benchmark condition (i.e., their threshold lies below the criterion) are omitted from further consideration. The benchmark condition represents a snapshot of a future scenario (defined as a combination of climate and non-climate conditions). It is generally convenient to use relative descriptors with respect to present values (see numerical example below).

4 **Eliminate adaptation strategies that overly exceed the benchmark condition.**

These strategies often represent very expensive solutions that offer an unnecessarily high level of protection even against highly improbable conditions.

5 **Finalize adaptation decisions using cost/benefit criteria.**

For the remaining strategies, perform a simplified cost-benefit analysis (CBA) to identify the most cost-efficient strategy that maximizes adaptation and resilience benefits. To allow a common basis of reference among alternatives, costs and benefits are estimated with respect to the "pass/fail condition."

The cost term should account for both the investment's CAPEX and its cost of residual risk. The latter can be ignored as relatively low. The benefit term represents the facility revenue (e.g. as a result of reduced maintenance and operational expenses) and the accomplished loss reduction.

OUTPUT

A preferred adaptation strategy for the water facility.

APPLICATION EXAMPLE - Part C

Question: What is a recommended adaptation strategy for the facility that will guarantee resilience against internal and external risks?

Rationale: Reverting to the impact and risk matrix of the preceding example (see Part B), the facility may experience severe operational disruption and significant revenue loss within a timeframe of 50 years if harsh climatic conditions are in place. In addition to that, it is projected that the agricultural activity in the region will grow.

To adapt to this changing landscape, the public authority examines three alternative adaptation strategies:

1. **Strategy 1:** "Do nothing" option (i.e., build the facility as it would otherwise be built and take no specific action for adapting to future conditions).
2. **Strategy 2:** Expand aquifer capacity by increasing the number of injection wells, and allocate resources to support the transition to smart irrigation for agricultural activities.

3. **Strategy 3:** In addition to Strategy 2, build a desalination treatment plant to further increase the water supply of the facility.

The strategies' threshold conditions (i.e., combinations of climate and non-climate conditions) are summarized in the table below. Following the methodology of **Tool 3.4**, the thresholds of each strategy are compared against the descriptors of the benchmark scenario (see **Tool 3.4** for definition) to exclude from further consideration strategies that will underperform in the benchmark scenario.

Here the benchmark future is defined as follows:

- Moderate drought conditions are expected to take place corresponding to annual temperature increases of greater than 1.5°C but lower than 4°C, with mean annual precipitation decreases on the order of 10 percent.
- Increase of water demand for agricultural activities: 10 to 30 percent.

Based on that, it is decided that Strategy 1 (apparently the less expensive one in terms of upfront CAPEX) cannot comply with the minimum planning requirements of the facility, as opposed to Strategies 2 and 3, which ensure adequate buffer against the projected socio-environmental changes.

TABLE 3.5 Threshold performance of the examined strategies

Strategy	Thresholds (climate and non-climate conditions)	Benchmark comparison
# 1	Mild climate projections (i.e., annual temperature increase < 1.5°C, mean annual precipitation decrease < 5%) Increase of water demand for agricultural activities < 10%	BELOW THRESHOLD
# 2	Harsh climate projections (i.e., annual temperature increase > 4°C, mean annual precipitation decrease > 15%) Increase of water demand for agricultural activities: 10-30%	ABOVE THRESHOLD
# 3	Harsh climate projections (i.e., annual temperature increase > 4°C, mean annual precipitation decrease > 15%) Increase of water demand for agricultural activities > 30%	ABOVE THRESHOLD

The next step is to filter out strategies that overly exceed the benchmark scenario descriptors (i.e., offer protection for a very severe and highly improbable scenario). No such strategy is identified herein and both Strategies 2 and 3 continue to the final appraisal stage, which qualitatively compares the cost/benefit of the two alternatives. A strategy is considered cost efficient if its accumulated benefits (due to reduced loss) over the facility lifetime (or the timeframe of the assessment) exceed the incremental additional expenditure for its implementation.

Using this rationale, Strategy 3 was abandoned because the cost of investing in extensive desalination was not justified by the potential benefits of the investment.

Answer: The public authority decided that Strategy 2 can provide the requested protection against the challenges of the future, and the associated costs are sensible and justifiable.

BOX 3.4 EXAMPLE OF ROBUST DECISION-MAKING: INLAND EMPIRE UTILITIES AGENCY

Southern California's Inland Empire Utilities Agency used robust decision-making to evaluate the impacts of climate change on long-term urban water management. The goal was to reject any water strategy that cost more than $3.75 billion. Scenario discovery using 21 climate models and a water management model concluded that the costs would exceed that figure if three things happened concurrently: large precipitation declines, large changes in the price of water imports, and reductions in the natural percolation into groundwater aquifers. Based on this, a management plan was devised that included: water-use efficiency, capturing stormwater for groundwater replenishment, water recycling, and importing water in wet years so groundwater can be extracted in dry years.

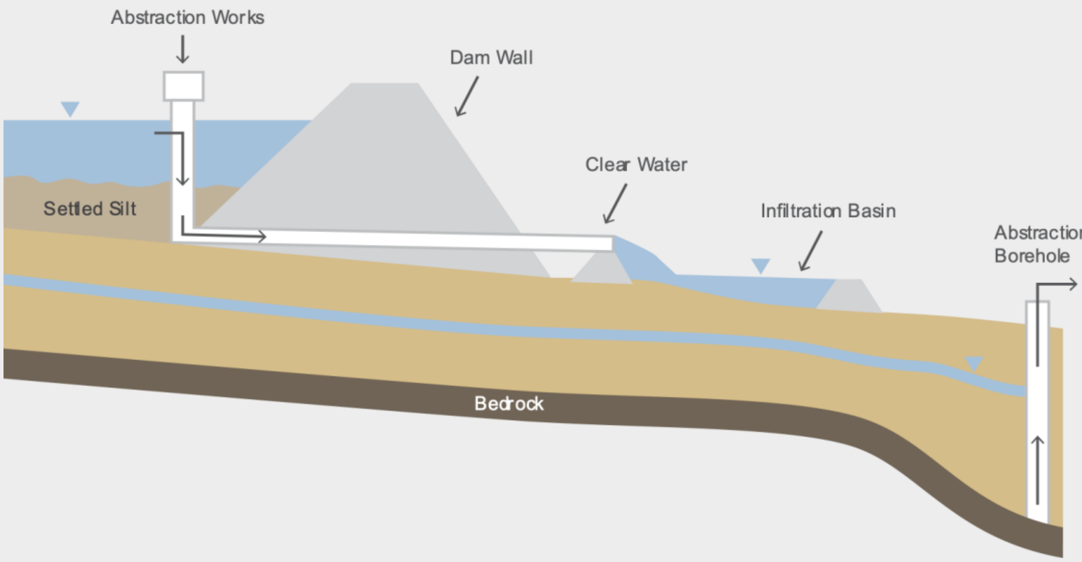
Source: United States Environmental Protection Agency. 2015. *Adaptation Strategies Guide for Water Utilities*.

BOX 3.5 ARTIFICIAL AQUIFER RECHARGE IN NAMIBIA

Namibia is the most arid country south of the Sahara, with scarce, unpredictable rainfall and perennial rivers only on its borders. Many Namibian settlements are situated in the coastal area of the arid Namib desert and depend on groundwater stored in the coastal aquifers of the ephemeral rivers. Withdrawal of groundwater at a rate greater than the natural replenishment rate causes a declining groundwater level, which may lead to decreased water supply, contamination of fresh water by intrusion of pollutant water from nearby sources, seawater intrusion into the aquifer of coastal areas, and other adverse effects.

To reverse this trend and increase natural replenishment, an artificial recharging of the aquifer was planned. The project consists of a dam with a storage capacity of 41 cubic megameter million cubic meters and a series of infiltration basins in the riverbed six kilometers downstream.

FIGURE B3.5.1 Schematization of the key elements of the project



Key elements of the scheme are illustrated in the figure above:

- The dam and associated storage in which the silt from flood waters can be allowed to settle.
- A multi-level off-take pipe to allow the transfer of clear water to the infiltration beds.
- Two large infiltration areas downstream of the dam.
- Silt removal around the abstraction tower.

The project successfully managed the water aridity issue. Despite the infrequent flooding, infiltration through the basins increased the annual recharge from 5.8 cubic megameter per year (Mm3/year) to 7.9 Mm3/year and the estimated sustainable yield increased from 2.8 Mm3/year to 4.6 Mm3/year. The capital cost of the project was $16.8 million, resulting in a very favorable unit cost of water of $0.25 per cubic meter.

Source: Braune, Eberhard, and Sumaya Israel. 2021. *Managed Aquifer Recharge: Southern Africa*. The Groundwater Project, Guelph, Ontario, Canada.

MODULE

4

Module 4

CLIMATE CONSIDERATIONS IN ASSESSING PROJECT'S ECONOMICS AND FINANCE

Module 4 is meant to support entities in including the previous climate considerations in their traditional economic assessments of Phase 1 "Project Identification and PPP Screening" in the PPP project cycle. To this end, this module consists of a single step that provides tools and examples for:

- Identifying all climate-related costs and benefits that should be integrated using an enhanced cost-benefit analysis (CBA) (**Tool 3.1**).
- Performing a value for money (VfM) assessment to determine whether the PPP should be preferred over traditional procurement after incorporation of climate considerations (**Tool 3.2**).

Adaptable to a wide range of water supply deployment projects, the *Handbook for the Economic Analysis of Water Supply Projects*[35] offers non-economists (regulators, policy makers, planners, engineers, financial analysts, sociologists) a broad view of the principles and methods for the economic evaluation of water supply projects. Integrating climate considerations (as recommended by this module) into the economic evaluation performed at the very early stages of the project cycle can reveal the undesired effects of climate change on the project's economics and finances, and raise awareness among the stakeholders.

[35] ADB (Asian Development Bank). 2002. *Handbook for the Economic Analysis of Water Supply Projects*. ADB. https://ppp.worldbank.org/public-private-partnership/library/handbook-economic-analysis-water-supply-projects.

Step 1

Check Economic Soundness Of Climate Strategies

SCOPE	To screen the enhanced project scope (employing climate strategies) from an economic perspective and to identify conditions that may hinder the project's affordability and suitability for PPP procurement.
PROCESS	Following the screening process presented in the Umbrella Toolkit, the economic analysis is performed in stages, starting with a preliminary CBA (**Tool 3.1**) to evaluate the cost/benefit ratio of the proposed climate strategies. For best results, all important climate-related costs (e.g., additional climate CAPEX, cost of disruption caused by extreme weather events) and benefits (e.g., risk reduction benefits, protection of the natural environment, and enhanced resilience of interdependent systems) should be synthesized and compared after economic evaluation. Then, the affordability of the project is tested in view of the budgetary limits, constraints, and other concurrent investment plans of the public authority, following the general considerations described in the Umbrella Toolkit. The final check is to assess how climate-induced risks, costs, and opportunities may affect the suitability of a project as a PPP (**Tool 3.2**).
	
TOOLS	**TOOL 4.1** Climate entry points for CBA (specific for water projects) **TOOL 4.2** Climate value drivers for VfM analysis
OUTPUT	A project that has successfully passed the preliminary economic appraisal screening and can hence receive the green light to proceed to the appraisal and preparation phase, where the technical design and the financial structure will be evaluated in much greater detail.

TOOL 4.1

CLIMATE ENTRY POINTS FOR WATER-SPECIFIC CBA

The tool describes entry points for climate-related CBA considerations that are relevant to water projects. Cost-benefit analyses are customarily conducted for different scenarios, accounting for changes in the financing scheme and operational processes, among others. Prior to applying the tool, users are advised to review methodologies for estimating the monetary value of social-environmental benefits and the CBA Primer (2017),[36] and to consult the Umbrella Toolkit (Module 1.3 and 2.3), where climate-related considerations for CBA (applicable to all sectors) are described in greater detail. Users are also encouraged to consult the Excel-based Risk Stress Test Tool (RiST),[37] developed by the World Bank to assess the economic viability of a project vis-à-vis climate risks.[38]

INPUT

TABLE 4.1 Water-specific climate entry points for CBA

CBA Process Outline*	CBA Sub-steps*	Climate Entry Point
Projecting financial data with conversion/ adjustment	Tax adjustment	• If applicable in the country, include tax incentives or expedited permitting that promotes climate mitigation and adaptation actions (e.g., loans from revolving funds or municipal bonds that have tax exemption status). • If applicable, include levies and environmental taxes in the "do nothing" option.
	Shadow price and opportunity cost adjustment	• Adjust costs and benefits as would otherwise be done following the 2017 WB Guidance Note on the shadow price of carbon.[39]
	Construction costs	• Include the cost of implementing the adaptation measures (e.g., cost of constructing higher capacity reservoirs, cost of diversifying options for water supply). • Include the costs for upgrades and of implementing energy efficiency management approaches. • Consider the cost of adopting sustainable/green construction principles (e.g., cost of recycling, reuse/resell opportunities, investment in electrical construction machinery).

[36] Guzman, A., and F. Estrázulas. 2012. "Full Speed Ahead: Economic Cost-Benefit Analyses Pave the Way for Decision-Making." *Handshake* 7 (October).
[37] Risk Stress Test Tool (RiST). https://www.worldbank.org/en/topic/climatechange/brief/risk-stress-test-tool.
[38] The analysis conducted by RiST is compatible with the methodological note "Integrating Climate Change and Natural Disasters in the Economic Analysis of Projects: A disaster and climate risk stress methodology."
[39] World Bank. 2017. "Shadow Price of Carbon in Economic Analysis." Guidance Note. https://thedocs.worldbank.org/en/doc/911381516303509498-0020022018/original/2017ShadowPriceofCarbonGuidanceNoteFINALCLEARED.pdf

CBA Process Outline*	CBA Sub-steps*	Climate Entry Point
		• For nature-based solutions, the cost of implementation may include the cost of land acquisition and of protecting, restoring and maintaining wetlands.
	Operational and maintenance costs	Operational and maintenance costs are expected to be particularly high for the "do nothing" option (which does not include climate adaptation/mitigation measures). The latter should account for the cost of: • Energy for operating the facility. • Rehabilitating physical losses and the cost of business disruption in the aftermath of disastrous climate events (adjusted over the probability of the event). This is the cost of residual risk (i.e., after the implementation of climate adaptation works). • Maintenance works (e.g., more frequent cleaning of canals/reservoirs caused by increased sedimentation rates, more frequent replacement of quickly deteriorating pumping systems). • Decommissioning of the equipment after completion of the project's productive life. Also consider the possibility of stricter reuse/recycling requirements in the future, resulting in increased expenses towards the end of the project's life.
	Term and residual value	Residual value estimates should be adjusted to include climate-change impacts, for example: • Reductions related to frequent weather-related damages. • Reductions caused by reduced water demand triggered by climate change (e.g., migration due to desertification). • Reductions caused by increased costs related to energy pricing and/or power availability.
Adding externalities	List of externalities	The cost of externalities should include: • Cost of disruption caused by power outages and broken supply chains. • Cost of emergency services (e.g., use of aerial means to extinguish fires or evacuate on-site personnel, or cost of maintaining backup supplies).
Adding socioeconomic benefits	Monetized benefits stemming from the implementation of climate adaptation/mitigation strategies	• Avoided losses to interconnected systems (e.g., reduced risk of combined sewer overflows during flood events). • Bolstering service continuity and coverage will increase tariffs and improve collection ratios. This will increase private investment confidence. Investing in climate mitigation stimulates the local economy and spurs development of energy-efficiency service markets. Most of these jobs will be performed by locals, which will be reflected in increased employment rates.
	Considering other unvalued benefits stemming from the implementation of climate adaptation/mitigation strategies	Other benefit streams may also include: • Environmental benefits (e.g., pollution reduction) as a result of the use of renewables or the adoption of nature-based/eco-friendly solutions. • Health benefits accrued by reducing the risk of infrastructure failure, meaning fewer people will be exposed less often to contaminated water, thus reducing the risk of infections. • Benefits to overall economic growth as a result of uninterrupted economic activity of water-dependent businesses (e.g., agricultural activity). • Community resilience benefits because critical services and key businesses rely on a resilient water infrastructure system, and safeguarding uninterrupted water service will help communities

CBA Process Outline*	CBA Sub-steps*	Climate Entry Point
		quickly recover from disruptive events and will reduce the economic impact of disasters. • Financing benefits because alignment with strategic climate objectives may unlock additional financing mechanisms for investors.
Relative price adjustments and bias/ risk adjustments	Market imperfection	• Apply as would otherwise have been done.
	Other opportunity cost adjustments	• Consider alternative uses of the land and space that climate measures cover, if any, and apply such costs.
	Taxes	• Same as above; apply only to the extent that tax advantages are applicable when a project exceeds its purpose in social benefits, and/or • Consider the tax income gained from steady uninterrupted operations.
Defining base case, defining and calculating economic internal rate of return (EIRR)	Discount rate definition and calculation of net present value (NPV) and EIRR	• Consider adjusting the discount rate for valuation depending on levels of certainty of cashflows (applies to projects that include climate adaptation measures) and uncertainty of cash flows (applies to alternatives with no adaptation measures). This needs to be aligned with the probabilistic analysis of events to avoid "hurting" a project with uncertainty twice (once with a high probability of costs occurring and once with a high discount rate because of the uncertainty of cashflows).
Incorporating uncertainty: sensitivities	Test the strength of the proposed business plan and present the effect of variations	• As would otherwise be conducted.

*(per APMG PPP Certification guide)

OUTPUT

A screening report highlighting which climate mitigation and adaptation aspects have been considered and ensuring these have been adequately evaluated.

IMPORTANT NOTE

Choosing Discount Rate

The discount rate used in the economic analysis is particularly important when evaluating and comparing adaptation options because the associated benefits (or avoided costs) are not likely to realize for many decades. There is no consensus on the appropriate discount rate to use for resilience strategies. As a good practice, study teams may choose to explore the sensitivity of economic analysis findings to different discount rates, or the possibility of applying a non-constant discount rate over the horizon of the assessment.

TOOL 4.2

CLIMATE VALUE DRIVERS FOR VFM ANALYSIS

A VfM analysis is performed to identify whether (and to what extent) climate-related risks, opportunities, and uncertainties may affect the suitability of a project for PPP and non-PPP delivery. The tool describes entry points for climate-related considerations for VfM analysis that are relevant to water projects. It explains the rationale of these considerations, identifies conditions of positive, negative, or conditional performance, and, where applicable, provides specific references and examples.

INPUT

TABLE 4.2 Impacts of climate change on PPP suitability for water projects

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
Project size	Is the project too big for the market? Or is the project too complex to be delivered as a PPP?	In cases where climate risks are high, the implementation of larger-scale interventions may be necessary. Examples may include: • Introduction of untested interventions for the region/country adaptation solutions (e.g., innovative technologies to remove pollutants for water treatment) • Developing high unit cost infrastructure assets • Cross-regional cooperation (to cope with water scarcity and increased demands). Such conditions will reduce confidence in cash flow generation, thus hindering investors' appetite and the project's financing.	**Negative**
Market appetite	Would there be private investor appetite?	When climate threats are not properly quantified, or when the impact of climate change cannot be properly assessed, the investing appetite decreases.	**Negative**
		Comprehensive climate risk assessments and a thorough CBA of climate adaptation/mitigation works would provide visibility and hence increase private sector appetite.	**Positive**
		Engagement with local communities and other stakeholders, and establishing an inclusive, participatory approach for climate adaptation planning will provide confidence that climate interventions are well received by the public and may bring broader socioeconomic benefits.	**Positive**
Precedent projects	Are precedent transactions already developed as PPPs for this type of project in the	Climate risks are better understood in countries with a legacy of water infrastructure development under a PPP scheme. The involved stakeholders are better informed, and the local communities are familiar with the services and benefits provided.	**Positive**

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
	country/region/similar countries?		
Risk allocation[40]	Are there any significant climate risks within the project that are not manageable by a private partner?	Water projects are notorious for having to cope with risks that are beyond the control of the private party (e.g., tariff regulation, poverty targeting, illegal settlements, unknown condition of the facility in case of change of hands). Climate change can act as a multiplier to some of these commonly encountered risks or create new ones (e.g., harsh climatic conditions could force migration and limit agricultural production, hence permanently affecting water demand). Advise **Table 3.3** for examples of climate externalities that cannot be controlled by the private party but that may negatively impact the project VfM.	**Negative**
		• **Comprehensive climate risk allocation** structure. • **Insurance coverage** against excessive internal risks (e.g., extreme climate events causing physical damage to water infrastructure, or extended periods of drought hampering the water supply capacity of the system). • **Well-designed overall sector reforms** (that regulate tariffs in a sustainable and socially acceptable manner, promote competition among providers, and provide incentives for enhanced energy/water efficiency).	**Positive**
	Are there circumstances where climate risks can be better assumed by the private party?	• The private sector's capital and innovation can create added value in energy efficiency management and in disaster preparedness, response, and recovery. • Insurance coverage also increases the capability of the private party to assume a certain level of climate risk.	**Positive**
	Is there a risk of non-availability of the land/right of way and land acquisition cost overrun?	This may be a risk for water projects working with wetlands and vegetation strips for flood protection, sedimentation control, and natural water filtration.	**Mostly negative**
Certainty of offtake/ supply	Is it possible that the project will experience a change in demand due to climate change?	Interdependencies between climate, population, water usage, energy supply, or disruptive new technologies render water-related development vulnerable to external factors that may not be under the control of the PPP and may have a negative impact on the demand for the water	**Mostly negative** (unless climate uncertainty and inter-dependencies

[40] The Global Infrastructure Hub's PPP Risk Allocation Tool (2019) (https://ppp-risk.gihub.org/) contains a matrix of risks typically found in water and waste PPP transactions (including water desalination, water distribution, and waste to energy plant project types), together with guidance on how those risks are typically allocated between the contracting authority and the private partner, the rationale for such risk allocation, mitigation measures, and possible government support arrangements.

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
		service and hence the tariffs, thus compromising investment certainty. Substantive increases in tariffs can also increase social and political risk.	have been properly addressed)
		Increased growth of a region (partially affected by milder climate conditions) may positively impact the water demand. Agricultural shifts toward water-depleting modes will increase water demand but may also generate water competition issues.	**Mostly positive**
Project quality	Will the project quality increase if the project is developed through a PPP scheme?	In several cases, the private party may bring innovation and high standards. Examples of such innovation applicable to water projects could indicatively include contractors with experience in the development of integrated energy monitoring systems for adaptive management and control of the water service, flood risk management, and early warning.	**Mostly positive** (provided that the methods used are tested)
		As commercial lenders become more informed on the climate-change risk, they will demand higher climate-resilience standards in order to ensure repayment/returns.	**Positive**
Output-based contracting	Is it possible to define clear output requirements for the project's performance to weather events?	The service availability and its quality could be linked with financial incentives or penalties to encourage faster and better responses to climate-related disruptions.	**Mostly positive**
Finance availability	Are there any significant climate risks that may harm the availability of financing?	Unmitigated risks (such as increased probability of high-impact weather events, water demand changes, geomorphological changes) will test the willingness of financiers to participate or could raise requests for higher guarantees.	**Negative** (unless recognized and proper adaptation measures are structured)
Legal or regulatory framework	Has the country adopted national legislation on climate change?	Prior existence of a national framework promoting green investments (defining subsidies and incentives for private sector participation) would definitely boost the project. For example, subsidies to invest in energy-efficient equipment upgrades, renewable energy generation, tax incentives for reducing carbon footprint.	**Mostly positive**

OUTPUT

The results of the VfM may be summarized in a screening report highlighting which climate mitigation and resilience aspects have been considered and how they are impacting the suitability of the project as a PPP.

MODULE

5

Module 5

KPIs FOR CLIMATE-RESILIENT AND SUSTAINABLE WATER PROJECTS

Key performance indicators (KPIs) are customarily used in water projects to assess and evaluate a project's performance during design, construction, and operation. KPIs are developed around specific government objectives, and the private partner will either be entitled to additional payments for good performance or to reduced payments for poor performance. Expanding this general notion to PPPs containing climate actions, the relevant KPIs can be used to measure the ability to prepare for, respond to and quickly recover from climatic hazards (i.e., resilience *of* the project) and the project's ability to contribute to society's climate-change adaptation (i.e., resilience *through* the project).

The tool described in the ensuing provides indicative high-level examples of climate KPIs soliciting forward-looking information to be included in performance-based contracts.

Based on the understanding that there is no one-size-fits-all for KPIs, the tool describes climate indicators that may be applicable to a broad range of water supply projects. It is then the obligation of the entity in charge, with the assistance of experts, to derive project-specific KPIs that best describe the technical/operational challenges of the project and take advantage of the expertise and innovation skills of the private sector. In establishing such targets, governments and their advisers must not forget that many urban water utilities in the developing world operate in difficult environments. Expectations about what can be realistically achieved given each situation need to be adjusted accordingly.[41]

[41] Marin, Philippe. 2009. *Public-private partnerships for urban water utilities: a review of experiences in developing countries*. World Bank and PPIAF.

TOOL 5.1

KPIS MEASURING CLIMATE RESILIENCE AND SUSTAINABILITY OBJECTIVES

This tool is designed to assist public authorities and their advisors when structuring and preparing performance-based contracts for water supply projects. The relevant KPIs included in this section have a dual purpose: (i) to facilitate assessments of a project's resilience to climate change and (ii) to track the effectiveness of the project in contributing to the sustainability and socio-environmental objectives of the country/region.

KPIs are typically described by a performance objective, a measurement indicator, and a threshold to measure compliance with the objective. It should be noted that the tool does not provide threshold values for the suggested KPIs. This is country- and project-specific information that the public authority should provide based on good-practice examples, applicable norms/rules, and in consultation with the technical advisor, in due consideration of the project's risk profile, the frequency of the event, and the importance of the project for the management of climate-induced risks. Overall, it is considered good practice to define two levels of achievement: a *conserving level* as one having no negative impacts, and an *improved level*, as one that will overall benefit the project's performance. Performance below the conserving level signifies the application of penalties, whereas performance above the improved level may be tied to specific rewards/incentives for the private partner.

INPUT

Tables 5.1 and **5.2** provide a non-exhaustive list of climate KPIs that can be widely adaptable to water supply projects and that have been recommended by international literature and frameworks.[42][43][44] The KPIs describe the project's performance according to resilience and sustainability goals covering its entire life cycle, from design and construction to operation and maintenance. Users are advised to revise/complete the list of KPIs to better reflect the project-specific goals.

TABLE 5.1 Indicative climate KPIs measuring the **climate resilience of the project**

Project Phase	Example Indicators
DESIGN/ CONSTRUCTION	**Climate-related design documents:** • Existence of climate and/or disaster risk assessments. • Existence of climate adaptation/resilience studies and plans. • Existence of emergency response plans addressing climate events. • Existence of a flood storage buffer.

[42] WAREG. 2017. *An Analysis of Water Efficiency KPIs In WAREG Member Countries*. https://www.wareg.org/documents/an-analysis-of-water-efficiency-kpis-in-wareg-member-countries/.
[43] IBNET (International Benchmarking Network) Indicators. https://www.ib-net.org/toolkit/ibnet-indicators/.
[44] World Bank Group climate indicators. https://data.worldbank.org/indicator?tab=featured.

Project Phase	Example Indicators
	• Amount of excess climate risks, i.e., the portion of climate risk that exceeds the respective provisions which the design of adaptation/resilience plans would have adhered to and efficiently addressed (*local currency*). • Percentage of excess climate risks that are covered by available insurance mechanisms (*%*).
	Adaptation/resilience measure implementation metrics: • Ratio of construction works (related to adaptation/resilience measures) completed/construction works planned (*%*) including auxiliary infrastructure (e.g., infrastructure to access and/or perform maintenance to the main bulk water infrastructure). • Existence of early warning systems. • Existence of redundancies.
OPERATIONS/ MAINTENANCE	**Impact metrics for climate-related disruptions:** • Number of climate-related incidents causing disruptions or requiring significant capital mobilization (*number/year*). • Number of users/customers affected by the water supply disruption (*number of users/year* or *number of users/event*). • Number of critical facilities (e.g., hospitals, schools, power plants) impacted by the water supply disruption (*number/year* or *number/event*). • Number of water distribution network elements/units affected by the water supply disruption (*number/year* or *number/event*). • Number of new water leakages (*number/event*). • Financial impact of the climate-related disruption, i.e., financial liabilities such as number of contractual fines (*cost/revenues*).
	Duration metrics for climate-related disruptions: • Total downtime, i.e., the time during which the water facility (or a specific element/unit) is out of service (*time unit,* e.g., *hours*). • Time to repair physical damages (*time unit*). • Time to receive spare parts for damaged equipment (*time unit*). • Time to restore operations and service continuity, i.e., the time required to restore a network or a service to a specific level of functionality (*time unit as a function of percent restoration*, e.g., 3 hours for 75% restoration; 1 day for 100% restoration). • Frequency of serious dam safety violations (*incidents/year*) and time required to completely address them (*hours*). • Time to discharge and time required to reduce reservoir level in order to achieve it (*hours*).
	Monitoring system: installation/operation of a robust/reliable monitoring system that includes weather forecasting modules. Example KPIs for the monitoring system: • Number of installed sensors (e.g., for identifying hotspots and extreme humidity levels in water treatment plants, erosion and sedimentation rates for reservoirs) and accuracy of sensors. • Data availability index (time that the monitoring system delivers data). • Data quality index (existence of quality control system).

TABLE 5.2 Indicative climate KPIs measuring **sustainability and environmental and social goals**

GOAL	Example Indicators
SUSTAINABLE/ ENVIRONMENTAL	**Carbon footprint metrics:** • Existence of a life-cycle analysis demonstrating project's GHG emissions (projected carbon dioxide equivalent (*CO_2e*)) and numerical targets for GHG emissions (*CO_2e/year*). • Emission intensities related to operations and maintenance activities (measured *CO_2e* and *methane*). • Primary and secondary suppliers of construction machinery/equipment that have sustainability or green sourcing/ procurement/management certification (% or *number*). • Energy efficiency - Total energy consumption (*kWh or kWh per m^3 of delivered water*). - Specific energy consumption for water treatment (*kWh/p.e.*[45]) or pumping energy consumption in the system (*kWh/m^3 at 100m water head*). - Energy mix (*% of participation of renewables in the energy consumed*). - On-site power generation (*%* or *kWh*). - Cost of power (*local currency/m^3 supplied/year*). - Energy recovery *(% of total energy consumption) by the use of pumps working as turbines (PATs)* . - Number of equipment upgrades (with higher energy efficiency), e.g., pump upgrades (*number/year*).
	Water efficiency • Water losses, i.e., leakage at transmission, leakage and overflows at storage tanks (*m^3 per km of network or as % of system input volume or Infrastructure Leakage Index*[46]). • Inefficiency of water resources use, i.e., real losses during the assessment period expressed as a percentage of the system input volume during the assessment period (*%*). • Reused supplied water (*%*). • Number of leaks detected and repaired (*number/year*). • Sustainable extraction of water, i.e., annual extraction from surface and groundwater, in relation to its minimum annual recharge (*%*).
	Water pollution • Water pollution incidents (*number/year*). • Number of water quality tests e.g., at the treatment facilities, at reservoir/storage facilities (*number/year*).
	Broader environmental metrics

[45] p.e. = population equivalent or unit per capita loading.
[46] The Infrastructure Leakage Index (ILI) is a performance indicator of real (physical) water loss from the supply network of water distribution systems developed by the International Water Association (IWA) and is defined as the ratio of Current Annual Real Losses (CARL) to system-specific Unavoidable Annual Real Losses (UARL).

GOAL	Example Indicators
	• Existence of environmental impact assessments. • Changes in biodiversity index. • Part of the revenues (*% or local currency*) from water sales that can be used for environmental services (e.g., forest management as part of watershed management). • Contribution of clean water supplied by the project as a percentage of the total freshwater resources[47] (*%*).
SOCIAL	• Complaints filed officially by users (after climate-related events) (*number/event*).
	• Existence and publication of a gender action plan,[48] including periodic reporting on its implementation status.
	Job opportunities • Number of new jobs created by the project (*number*). • Number of new jobs that were covered by locals and/or women, including positions related to climate change issues and adaptation/mitigation measures (*%*). • Percentage of senior/managerial positions held by women (relative to regional averages) (*%*). • Existence of gender equality objectives in hiring. **Social inclusion** • Expansion (*% or absolute value*) in the number of water. points/yard taps in order to reduce the time women and girls have to walk to offsite water. • Existence of adequate provisions/instruments to alleviate the disproportionate impact caused for vulnerable populations by an increase in tariffs (in case such an increase is caused by the PPP project).
	• Raising public awareness campaigns (*number/year*).

OUTPUT

Project-specific climate KPIs for consideration in the project documentation/contract.

[47] The water stress indicator of a watershed shows how much freshwater is being withdrawn by all economic activities, compared to the total renewable freshwater resources available. It also takes into account environmental flow requirements. For more information, see UN-Water's Indicator 6.4.2: https://www.unwater.org/our-work/integrated-monitoring-initiative-sdg-6/indicator-642-level-water-stress-freshwater.

[48] Enhancing the role of women (and vulnerable people in general) in the project is expected to have a catalytic effect on their ability to cope with the adverse effects of climate change. An example of a gender action plan for a water supply project may be found in the Dili West Water Supply Project in Timor-Leste: https://www.adb.org/projects/documents/tim-54429-001-gap. The World Bank Group's 2021 document "Green, Resilient and Inclusive Development (GRID)" provides further guidance on gender aspects. https://thedocs.worldbank.org/en/doc/9385bfef1c330ed6ed972dd9e70d0fb7-0200022021/green-resilient-and-inclusive-development-grid.

Summary and Conclusions

CLIMATE ENTRY POINTS IN THE EARLY STAGES OF A WATER PRODUCTION AND TREATMENT PPP PROJECT'S PREPARATION

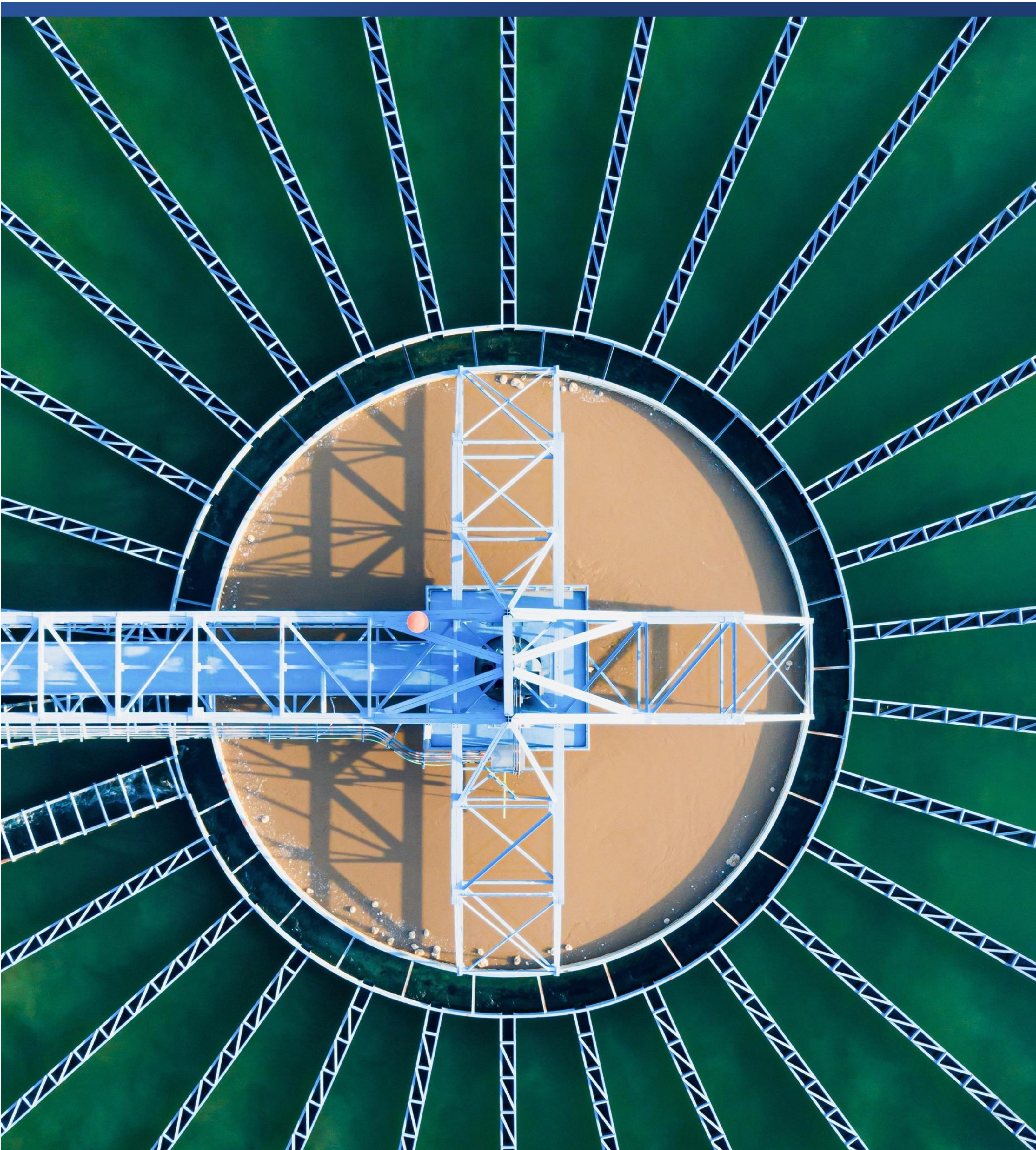
After completion of all the steps described in this toolkit, users are expected to have a clear view of how to incorporate climate considerations into the early stages of a bulk water PPP project's preparation, using a set of practical tools that allow:

- **Identification and mapping of the national and international climate-related frameworks** and commitments relevant to the project under consideration. To this end, the tool helps users navigate the main documents defining such policies, while guiding them as to the specific focus areas that are of importance for bulk water PPP projects.
- **Screening of the alignment of the water production and treatment PPP project with the Paris Agreement** and the regulations stemming from it. Screening is performed by means of four sets of questionnaires—each referring to one pillar of the relevant considerations—through which users are able to identify areas where improvements may be necessary, recalling that all WBG-supported projects must be fully aligned with the Paris Agreement by 2025.
- **Estimation of the carbon footprint of the project,** by performing a preliminary assessment of the GHG emissions associated with the construction and operation of the bulk water facility. The relevant tools offer step-by-step instructions on how to provide a preliminary life-cycle assessment (LCA) of such emissions, supported by a list of international resources for assessing emissions associated with each (construction or operation-related) activity.
- **Identification of applicable mitigation measures** that can be applied to reduce the emissions of various project components. To this end, the toolkit analyzes opportunities for GHG reduction and energy savings in several parts of bulk water projects, including extraction, storage, conveyance, and treatment .
- **Appraisal of the climate-related risks that the specific project is exposed to,** which are defined as the potential losses that could be either internal to the project (in the form of physical damage and loss of revenues due to a climate event immediately impacting the operability of the infrastructure) or external (in the form of economic losses due to an acute event or chronic hazard impacting the operation of the facility, which may remain physically intact). To this end, several readily available online resources are provided that allow users to understand which hazards may affect the project, given its location and the plant components. Based on such data, the potential effects of each hazard on specific project assets may be assessed. Hence, users will be able to form a preliminary opinion as to the vulnerability of each asset type, its appropriateness for the project/region, and the associated needs for risk reduction measures.
- **Preliminary exploration of climate adaptation and resilience strategies** aimed at reducing the risks identified above and enhancing the project's bankability. Users are guided through the relevant tools enabling identification of adaptation measures for their bulk water project, while at the same time providing a high-level indication as to the costs and benefits of each alternative option so that users are able to design different resilience strategies—each with distinct costs and benefits.
- **Preliminary identification of climate entry points in the cost-benefit analysis of the project,** using a step-by-step approach that supports users in understanding how climate risks, as well as adaptation

and resilience plans, may be reflected in the project economics, by presenting the tradeoffs between climate-related risks and investments.

- **Preliminary appraisal of the project's VfM and suitability as a PPP,** using a set of tabulated instructions explaining the effects of the various potential climate actions identified above on parameters such as project bankability, investor appetite, and project risk profile. It is also shown how failure to act—or invest—may result in a negative impact on the project if investor risks remain unmitigated, or if insufficient measures hamper the eligibility of the project to receive funding from multiple sources.
- **Preliminary identification of climate (mitigation- or adaptation-related) KPIs** that could be used to trigger climate-related clauses of the payment mechanisms in PPP contracts. It is shown that climate considerations are meant to be present in all phases of the PPP project—from project selection, design, and construction through project implementation. To this end, a non-exhaustive set of essential climate-related KPIs is presented as part of the relevant tools that describe bulk-water-specific actions and quantifiers to allow them to be monitored.

This toolkit, when used in conjunction with the WBG's Umbrella Toolkit, is meant to support PPP agencies operating in EMDE countries in incorporating climate risks and opportunities in bulk water PPP projects, by providing detailed guidance applicable to the early stages of such projects' preparation. Given the importance and complexity of incorporating climate change in PPP projects, all appraisals performed at the preliminary stages with the help of this toolkit will need to be reassessed in detail with the help of expert consultants on the basis of project-specific data that will become available in subsequent stages of the project.



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