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WORKING PAPER

ACHIEVING ABUNDANCE: UNDERSTANDING THE COST OF A SUSTAINABLE WATER FUTURE

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EXECUTIVE SUMMARY

Highlights

- Population and economic growth, as well as climate change, have pushed water crises to the top of the global agenda.
- Given the scale of the issues, delivering sustainable water management requires rapid mobilization of funding for water-related improvements and more effective use of existing resources.
- This Working Paper proposes a method whereby any decision-maker can calculate the cost required to deliver sustainable water management to a geography.
- The Proposed Approach calculates the cost of action required to close the gap between current conditions and desired conditions to financially compare and prioritize different water-related challenges or different targets of Sustainable Development Goal 6.
- The paper also estimates the costs of delivering sustainable water management for all countries and major basins—estimated globally as US$1.04 trillion (2015$) annually from 2015 to 2030.
- The Proposed Approach and Estimated Cost data set were designed for private sector applications, but a variety of decision-makers will find value in these tools to improve the effectiveness of financing for sustainable water management.

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues. Working papers may eventually be published in another form and their content may be revised.

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Box 1 | **Abbreviations**

AWS	Alliance for Water Stewardship
BMP	best management practices
IRWM	integrated water resources management
OECD	Organisation for Economic Co-operation and Development
PPP	purchasing power parity
SDG	Sustainable Development Goal
WASH	water access, sanitation, and hygiene
WHO	World Health Organization
WPL	water pollution level
WRG	2030 Water Resources Group

Water crises are increasingly at the top of the global agenda and will only worsen given the combined effects of population growth, economic growth, and climate change. In 2015, countries and companies committed to the Sustainable Development Goals (SDGs)—including SDG 6, which calls on member nations to "ensure availability and sustainable management of water and sanitation for all" by 2030 (United Nations 2015). SDG 6 and its targets are ambitious and require rapid mobilization of financial resources, effective prioritization of funding, and a deeper understanding of the different types of water challenges and solutions.

This Working Paper has been developed for a private sector audience, but it is flexible and applicable to the public sector, investors, and other decision-makers seeking to improve water resource management. It attempts to identify the financial cost of delivering sustainable water management. To do so, the paper offers two outputs: first, a flexible Proposed Approach that can be applied to any geography to estimate the cost of sustainable water management; and second, a global set of Estimated Costs (in 2015$) for countries to deliver sustainable water management, which offers a deeper understanding of the magnitude of the task before us.

The Proposed Approach is flexible, so decision-makers can calculate the cost of resolving water-related challenges within a geography. Water-related challenges could be the targets of SDG 6, but broader or narrower sets of water challenges could also be assessed, depending on the context. The Proposed Approach is intended to provide a standard approach for measuring cost and to allow for some comparability (in monetary terms) between different types of water challenges. The cost of addressing each water challenge can be assessed using two inputs: a Projected Gap, or the estimated magnitude of a water challenge, and a Solution Cost, or the cost of a suite of solutions that can be feasibly applied to close a given Projected Gap. Each water challenge has a Projected Gap and a Solution Cost, and outputs an Estimated Cost, which is the cost of resolving a given water challenge within a chosen time frame.

The globally generated data set provides Estimated Costs for all countries and major basins to deliver sustainable water management using existing global data and the proposed calculation method. These Estimated Costs are not intended as a final say, but as a way to improve our understanding of the issues, progress existing models, and drive tangible action. In this calculation, sustainable water management addresses the following: access to drinking water, access to sanitation, reduced water pollution, reduced water scarcity, and the additional cost of water management associated with these prior water challenges. This paper estimates that delivering sustainable water management requires an annual cost of $1.04 trillion (2015$) for the time period 2015–30. Water scarcity is the single largest cost driver within this $1.04 trillion due to the need to close the gap between global renewable water supply and demand. Specifically, this paper estimates the projected 2030 global water gap at 2,680 cubic kilometers (km^3) and a total annual withdrawal of 4,670 km^3: in short, the gap accounts for 56 percent of total 2030 withdrawals.

The Proposed Approach and Global Estimated Costs are intended to give decision-makers better tools to evaluate water-related investments. These tools are not intended to stand alone but rather to be incorporated into the financing, prioritization, and policy-making decisions within each context. The authors do not intend to prescribe specific applications for the Estimated Costs, though some possibilities include prioritizing capital funding or loans, tracking SDG 6 investment opportunities, screening portfolios or supply chain risks, developing national water policy, and informing multilateral stakeholder discussions. The need to better understand the costs associated with delivering sustainable water management requires further research, and the accuracy and comprehensiveness of this work will be improved over time. Nevertheless, at this time and given the current research landscape, this Working Paper provides robust tools that can improve the delivery of sustainable water management globally.

1. INTRODUCTION: CHALLENGES TO SUSTAINABLE WATER MANAGEMENT

The World Economic Forum's *Global Risks Report 2019* ranks water crises among the top global risks, based on possible impacts and likelihood (WEF 2019). This paper predicts that by 2030, population growth, economic development, and the global climate crisis will cause the world's water withdrawals to exceed global renewable supplies by as much as 2,680 cubic kilometers (km^3) annually. In addition to these challenges, the loss of natural capital worldwide, the lack of investments in existing infrastructure, and the inefficient allocation and distribution of water increasingly threaten limited water supplies. This mismanagement of water resources poses critical harm to society, businesses, and the environment (CDP 2017). Recent examples of water crises include those in Southern California; Cape Town, South Africa; Chennai, India; and São Paulo, Brazil, all of which significantly impacted local societies and economies (CDP 2015; Otto and Schleifer 2018; Palanichamy 2019).

To generate the momentum needed to respond to water challenges, the United Nations developed Sustainable Development Goal 6 (SDG 6) in 2015, which calls on all member nations to "ensure availability and sustainable management of water and sanitation for all" (United Nations 2015). Country commitments to SDG 6 have been paralleled in the private sector by an increasing corporate commitment to water stewardship, which is "the use of water that is socially and culturally equitable, environmentally sustainable and economically beneficial, achieved through a stakeholder-inclusive process that involves and catchment-based actions" (Alliance for Water Stewardship 2019). This paper seeks to support public decision-makers in achieving SDG 6 and private sector actors in delivering water stewardship. There are many other frameworks and concepts for understanding the complexities and variety of water-related challenges, but for simplicity this paper adopts the framing of SDG 6.

Beneath the umbrella of SDG 6 are a variety of water-related objectives. Some of these, such as the need to achieve universal access to drinking water, have been studied in detail and robust global cost estimates of meeting the objectives have been developed (Hutton and Varughese 2016). Other objectives have garnered less attention and lack the frameworks or data needed to understand the magnitude of investment globally or per country. This paper provides a unifying framework to understand the costs needed to achieve SDG 6 within all countries and major basins. Currently, the authors believe that no approach exists to calculate the cost of delivering sustainable water management *as a whole*.

Although each aspect of SDG 6 is calculated individually, this paper calculates each target using a common framework. This framework allows for better comparison and prioritization of investments and can guide decision-making and investment towards the most efficient resolution of our shared water challenges. Further, the method is intentionally flexible and designed to go beyond the ambitions of SDG 6 to encompass water stewardship objectives or generally be adapted to decision-makers' needs.

In addition to providing a method for estimating the cost of achieving SDG 6, this paper uses global data to estimate what this will cost, globally, by country and major basin. This global data set is not intended to provide exact costs but rather serve to improve decision-making and drive the actions needed to deliver sustainable water management by 2030.

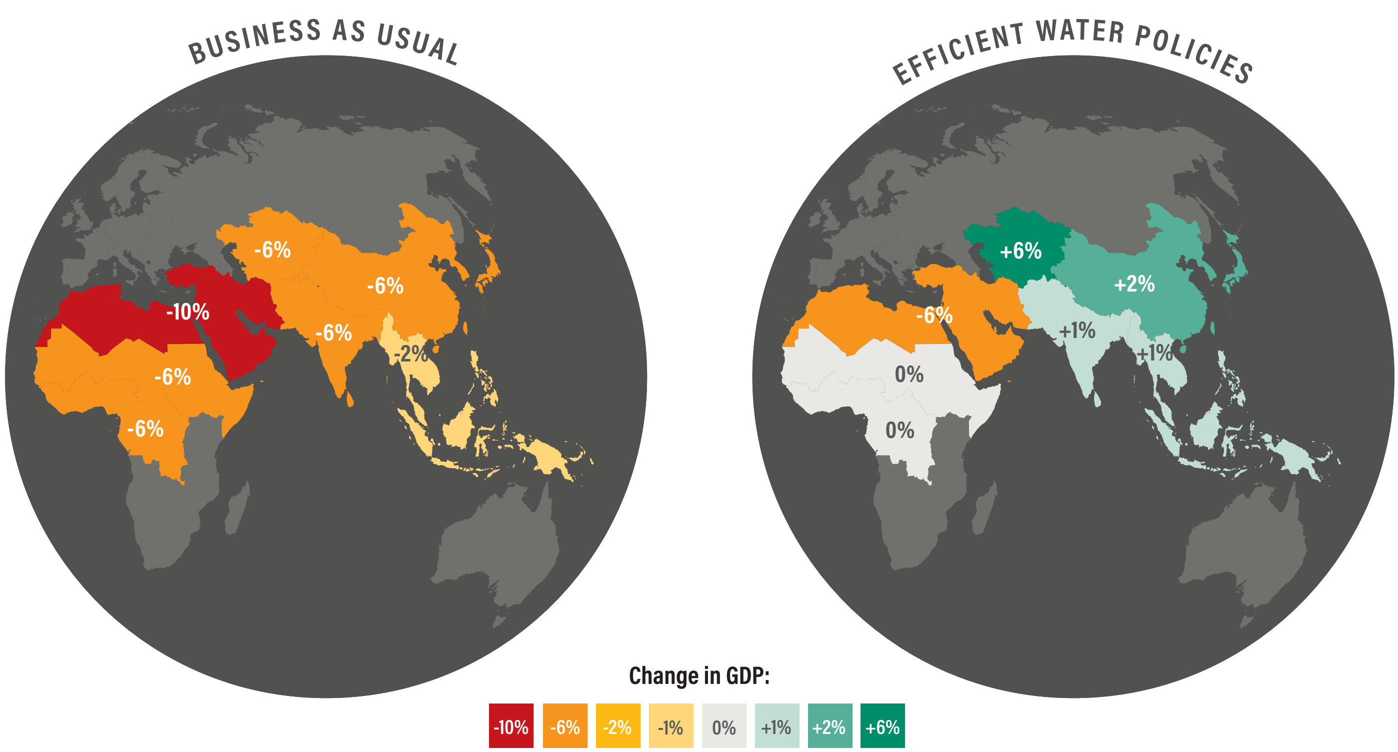
The Benefits of Sustainable and Accessible Water Management

There are already many assessments of the economic consequences of inaction or the benefits of investing in water resources. The drive to achieve SDG 6 is not investment for investment's sake; there are substantial social, economic, and environmental benefits to sustainably managing water resources. In economic terms, different studies have identified the following benefits:

- Hutton (2012) estimates the return on investment ratio for water access, sanitation, and hygiene (WASH) services ranges from 0.6 to 8.0. The investment return on sanitation services is on average higher (5.5) than water access services (2.0). The primary drivers of these economic benefits are health-related improvements and fewer deaths associated with water-related diseases.
- The World Bank estimates that regional GDP (gross domestic product) decline can be avoided through more efficient water allocation and policies. Largely driven by increasing water scarcity, by 2050 many regions may experience up to a 6 percent decline in GDP (World Bank 2016) (see Figure 1).
- Sadoff et al. (2015) estimated the benefit of reducing the water scarcity risk globally for agriculture at US$94 billion annually.
- For nutrient pollution in water bodies, Abell et al. (2017) estimated that one in six cities (of a sample of 4,000) implementing source protection measures could net immediate positive returns through reduced water treatment costs. Additional knock-on benefits that are more difficult to measure include improved local health and well-being, higher biodiversity value, and carbon value stacked on top of water treatment saving.[1]

There are many approaches to estimate the cost, benefit, and value of water for different stakeholders and different water uses.[2] This Working Paper focuses on the cost of action to solve water-related challenges using a comprehensive, replicable, and flexible method.

Figure 1 | **Estimated Change in 2050 GDP Due to Water Scarcity, under Business-as-Usual Policy Regime**



Source: Global Commission on Adaptation 2019, World Bank 2016.

2. OBJECTIVE

This paper seeks to provide tools and insights for understanding the cost of achieving sustainable water management. Here, *sustainable water management* is shorthand for the objective laid out in SDG 6: to "ensure availability and sustainable management of water and sanitation for all." We use the term *water challenge* to refer to specific water-related issues, such as lack of access to drinking water or industrial water pollution.

To better understand the cost of delivering sustainable water management, this paper seeks to do the following:

- Propose a standard approach to assess the cost of action required to deliver sustainable water management to a given location. This approach estimates the cost of sustainable water management by assessing the cost of interventions required to bring current water-related conditions up to a desired state by 2030. It is intended for use at any scale (depending on the quality of data inputs) to better inform water-related decision-making.
- Generate an Estimated Cost of delivering sustainable water management by 2030 to countries and major basins. These estimates draw on global data and are not intended to inform local decisions; however, the Estimated Costs do offer a starting point for understanding where we are globally in terms of delivering sustainable water management to all.

These resources were initially designed for a private sector audience, but other audiences will also benefit from the Proposed Approach and Estimated Costs. A common approach to understanding the cost of delivering sustainable water management is valuable to set a standard for understanding the financing gap between the current state of water resource management and the desired future end states. National and local governments, or utilities, could apply the Proposed Approach using local data to better assess the financial limitations of delivering sustainable water management. However, the Estimated Costs do not address indirect and societal costs and benefits; therefore, the Estimated Costs can only provide one piece of the puzzle for public sector decisions.

The Estimated Costs offer data to chart the current state of water resources and measure how far the world is from delivering sustainable water management. They allow regional trends to be highlighted, water challenges to be compared, and the magnitude of the tasks ahead to be estimated. Decision-makers interested in the Estimated Costs include multilateral development banks, international companies, financing institutions, and national governments—actors that have a need for global or regional estimates to inform strategic activities.

Although the many benefits have been noted, there are important caveats to the Estimated Costs. Experts in the field know the complexity of the objectives outlined above. Data quality limitations and other uncertainties abound. Likewise, there is no consensus on the most robust approach to understanding certain water challenges. When possible, this paper follows established methods or data sets and uses new alternatives when necessary.

The authors do not assert that the methods and data sets used are the best approaches. Instead, they merely suggest that, using the best feasible resources and given data limitations, these methods put forth a globally comparable, robust approach to estimating the costs of delivering sustainable water management. An ongoing conversation on calculation methods, data limitations, and viable applications of this work is necessary—all contributions to improve the value and accuracy of the Proposed Approach and Estimated Costs are welcome.

3. INFORMING DECISIONS: AN APPROACH TO UNDERSTANDING COSTS

This paper proposes an approach to understanding the cost to deliver sustainable water management. The approach is intended to be flexible and adapted to decision-makers' specific needs. It is not intended to be prescriptive but rather to offer guidance to estimate the cost of delivering sustainable water management at any scale, with suitable data inputs. For a discussion on the data inputs and calculation methods used for Estimated Costs, see Appendix A.

The cost of delivering sustainable water management is, in this paper, the sum of required costs to eliminate the water challenges identified in SDG 6, within a country or major basin, by 2030. The Total Estimated Cost accounts for the annual needs of operations, maintenance, and capital expenditure[3] required to close the gap between current and desired end states.

- **Projected Gap:** the gap between current and desired end states, measured as a negative impact. For example, a volume of untreated wastewater or a population without access to drinking water.
- **Solution Costs:** the set of solutions required to reduce or eliminate a Projected Gap. The Solution Costs are measured as the cost or range of costs to eliminate one unit of the Projected Gap—for example, the cost per cubic meter ($/m^3) required to treat untreated wastewater.
- **Estimated Cost:** the cost to reduce or eliminate a negative Projected Gap, measured in US$ or local currency. The Estimated Cost is calculated by multiplying the Projected Gap and the Solution Costs (Equations 1 and 2).
- **Total Estimated Cost:** the sum of all Estimated Costs for a country or major basin, representing the total expenses needed to achieve sustainable water management (Equation 2). When referring to the Total Estimated Cost for the world, the Working Paper uses the term *Global Estimated Cost*.

Equation 1: Estimated Cost Formula

$$Estimated\ Cost_i = \sum_j Projected\ Gap_i \cdot Solution\ Costs_{ij}$$

i: SDG 6 target
j: Solution Costs

Equation 2: Total Estimated Cost Formula

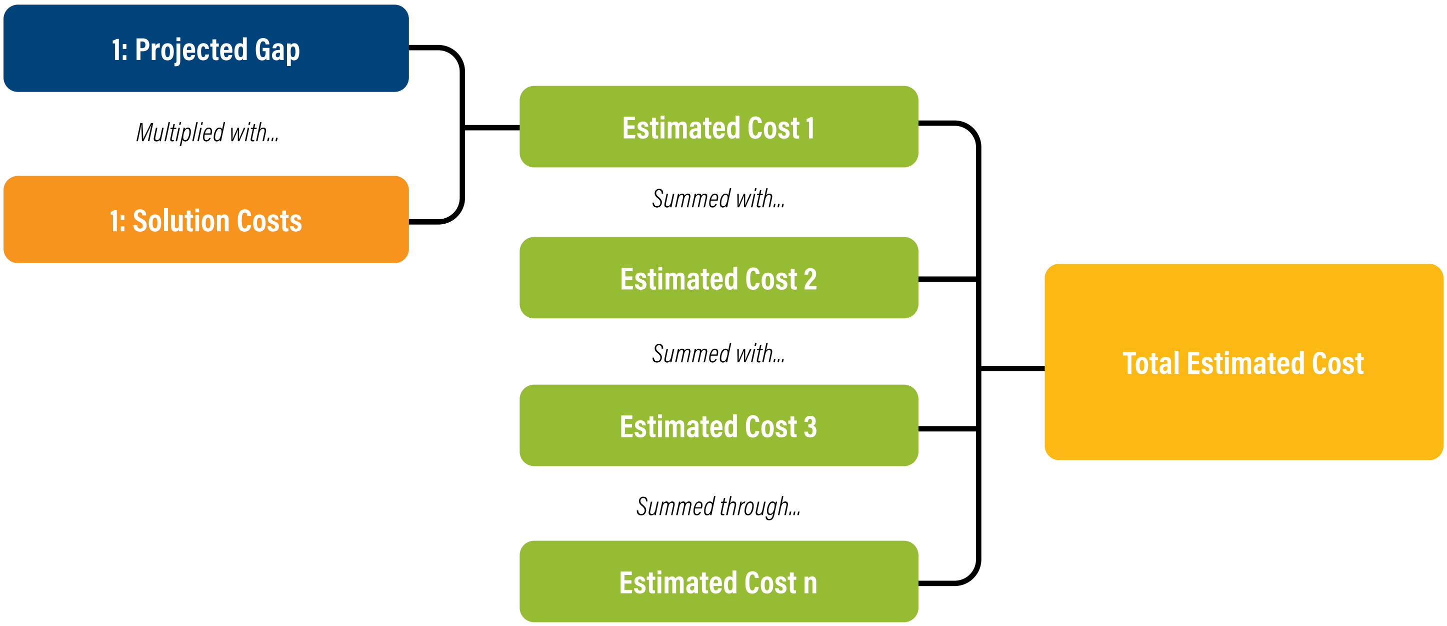
$$Total\ Estimated\ Cost = \sum_i Estimated\ Cost_i$$

i: SDG 6 target

See Figure 2 for a summary of Projected Gap, Solution Costs, Estimated Costs, and Total Estimated Cost. The Projected Gap measures the gap between current baseline conditions and a desired end state; if current conditions are the desired end state, then there is no Projected Gap. Since the Solution Costs are only applied to the Projected Gap, the Estimated Cost does not account for expenditures required to maintain the current baseline. Alternatively, existing activities that are already financed—or, in some instances, processes that exist but are accumulating debt—are not accounted for in the Proposed Approach.

The Proposed Approach estimates the cost of resolving water-related issues, but it ignores the social, economic, or environmental benefits of resolving these issues. For example, the full benefit of delivering universal access to safely managed sanitation is not calculated here. Consequently, although the Estimated Cost is a useful tool to understand overall investment needs, the relative prioritization of SDG 6 targets should be determined on a local basis by relevant stakeholders—for example, based on the economic or social return on investment.

Figure 2 | **Summary of Calculation Method**



Note: The Total Estimated Cost is the sum of all separate Estimated Costs, and each Estimated Cost is generated by multiplying a Projected Gap and its respective Solution Costs.
Source: Authors.

Data Considerations

The value and applicability of each Estimated Cost is contingent on the quality and geospatial resolution of input data. When possible, the Estimated Costs displayed in Section 4, "Global Results," adhere to these crucial data considerations (see Appendix A for further discussion). Several considerations are necessary when considering input data:

- **Time frame.** Data for a Projected Gap must account for current and future conditions. For example, estimating the cost to deliver drinking water services by 2030 requires robust data sets on projected populations. Data on Solution Costs are more complex. Projecting the future cost of solutions requires unknown assumptions on the frequency and magnitude of technological breakthroughs or using Solution Costs that reflect current technology and cost levels.

- **Multiple solutions.** Addressing a Projected Gap may require a set of solutions rather than a single solution on its own. Maximizing the accuracy and applicability of Solution Costs requires
  - multiple types of solutions for the same Projected Gap, to account for the fact that no single solution will resolve an entire water challenge;
  - a geospatial component to Solution Costs, accounting for the different cost of similar solutions in different countries; and
  - an implementation capacity for each solution, addressing the feasibility of a solution to deliver results to a country or basin.

- **Double counting.** Different aspects of sustainable water management are intertwined, meaning that Projected Gaps can also overlap. Similarly, Solution Costs can address more than one Projected Gap. Therefore, caution is needed when selecting data for Projected Gaps to prevent double counting Estimated Costs across different SDG 6 targets. For example, delivering domestic wastewater treatment services falls under SDG 6.2 and SDG 6.3 because wastewater treatment services influence both access to safely managed sanitation and water pollution.

- **Consistent metrics.** The Proposed Approach is intended to incorporate capital, operations, and maintenance costs. However, using consistent financial metrics for different Solution Costs is important to generate a comparable Estimated Cost. For example, if not all Solution Costs incorporate operations and maintenance costs, the costs are not easily compared. However, metric consistency must also be balanced with data availability and quality.

The Proposed Approach is intended to provide flexible guidance for identifying and comparing investments in sustainable water management, and these considerations drastically affect the output of each Estimated Cost, with important implications for how each Estimated Cost is used in decision-making. Effectively applying this Proposed Approach in a local context requires users to consider primary data availability and quality, feasible inputs (Projected Gaps and Solution Costs), and how Estimated Costs can be used to support decisions.

Calculating SDG 6

SDG 6 offers a starting point to understand the various water-related challenges different decision-makers face (Figure 3). Ultimately, however, context determines each user's challenges. Only some aspects of SDG 6 may be relevant to a decision-maker's local context; for other decision-makers, SDG 6 may not be ambitious enough to fully deliver sustainable water management.

Given the complex needs of different decision-makers, the Proposed Approach is intentionally flexible so decision-makers can calculate the investment needed to eliminate their most relevant water-related issues. The targets outlined in SDG 6 provide the recommended starting point for applying the Proposed Approach; however, decision-makers' local objectives should determine the Projected Gaps.

Figure 3 | **SDG 6 Targets Summary**

6.1 All have access to safe and affordable drinking water

6.2 All have access to adequate sanitation and hygiene, and open defecation is eliminated

6.3 Improve water quality by reducing pollution, minimizing release of hazardous chemicals, and halving the proportion of untreated wastewater

6.4 Increase water efficiency across all sectors and ensure sustainable supply of water to reduce the number of people suffering from water scarcity

6.5 Fully implement integrated water resources management—which looks at water resources holistically

6.6 Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

Note: In addition to these above targets the United Nations also has SDG targets 6A and 6B, on water and sanitation-related implementation.
Source: United Nations 2015.

4. GLOBAL RESULTS

This Working Paper generated Estimated Costs using global data for different aspects of SDG 6 for all countries and major basins to achieve sustainable water management. The sum of all Total Estimated Costs for all countries is the Global Estimated Costs. The Global Estimated Costs serve the following purposes:

- To understand—at a macro level—where the world stands with respect to delivering universal sustainable water management.
- To lay a foundation for future estimates and improve understanding of water resource management challenges.
- To demonstrate how the Proposed Approach can be implemented by providing a concrete example of the calculation process.

The Global Estimated Costs cover all geographies, and the results are available at the country and major river basin scale, although the country perspective is presented here. Metadata and calculation methods are detailed in Appendix A.

This paper begins with the targets outlined in SDG 6. However, the primary objective is to calculate the cost of delivering sustainable water management, so our calculations do not completely match SDG 6 targets. These calculations were decided based on available global data sets and in an effort to provide a comprehensive view of the cost to achieve sustainable water management. The Estimated Costs and Projected Gaps include the cost to

- achieve universal access to drinking water (SDG 6.1);
- achieve universal access to sanitation and basic hygiene and eliminate open defecation (SDG 6.2);
- treat all industrial wastewater discharge to tertiary treatment standards (SDG 6.3);
- reduce agricultural nutrient pollution to achieve acceptable concentrations of nutrients in water bodies (SDG 6.3);
- eliminate water scarcity by reducing the ratio of water demand (human and environmental) to renewable water supply to within acceptable boundaries (SDG 6.4); and
- increase regulation and management of water resources in line with the need to manage the above water-related investments (SDG 6.5).

Although conserving water-related ecosystems (SDG 6.6) is not explicitly addressed in this framework, these calculations incorporate many aspects of ecosystem protection within existing calculations. For example, ensuring suitable environmental flow rates is captured in the cost of eliminating water scarcity; pollution and eutrophication in ecosystems is addressed in reducing or eliminating domestic, industrial, and agricultural pollution. That said, this paper does not calculate the costs to

- fully finance, maintain, and operate existing water and wastewater treatment and distribution infrastructure—that is, the debt of current infrastructure is not taken into account;
- establish land conservation and restoration mechanisms to protect water-related ecosystems from land-use change (SDG 6.6);
- increase flood protection to reduce human and economic exposure to riverine and coastal flooding;
- increase drought resilience through policy and regulatory mechanisms and emergency water efficiency measures; or
- develop effective transboundary management of water resources (SDG 6.5).

Many of these exclusions are important aspects of sustainable water management. However, the decision to include or exclude different costs was based on the quality and availability of data. For example, assessing the cost to reduce nutrient pollution from agricultural sources was considered more feasible (given existing data) than assessing the cost to improve ambient water quality. Alternatively, the cost of developing effective transboundary management of water resources was considered too complex to calculate given current data.

Even with these gaps, this paper represents a more holistic attempt to understand the cost of sustainable water management. Future iterations of this project may include new Estimated Costs not currently accounted for and improved calculation methods as data quality and availability improve.

General Clarifications

The following points are important to keep in mind when interpreting the Global Estimated Costs discussed:

- **Currency.** All Solution Costs were normalized to 2015$ before calculating each country's Estimated Costs. All final Estimated Costs have been adjusted for a country's respective purchasing power parity (PPP) to make costs comparable.
- **Time frame.** The objective of this paper's calculations was to identify an annual Estimated Cost for countries to deliver sustainable water management. To arrive at this, Estimated Costs represent required annual costs between 2015 and 2030 to match the time frame of the SDGs.
- **Multiple solutions.** Rather than apply single Solution Costs, wherever possible, a suite of relevant Solution Costs was developed from the existing literature. The quality and geospatial extent of Solution Costs varies widely, but the application of PPP to Solution Costs provides a basic geospatial component to all Solution Costs.
- **Double counting.** Projected Gaps have been scoped to eliminate double counting whenever possible. For example, calculations on water pollution only account for industrial and agricultural pollution (SDG 6.3) because the Estimated Cost for domestic wastewater treatment is assumed to be covered as part of delivering universal access to basic and safely managed sanitation (SDG 6.2). See Appendix A for calculation details.
- **Interpreting Estimated Costs.** Wherever possible, Estimated Costs include capital expenditures as well as the additional operations and maintenance costs associated with new capital expenditures. Solution Costs have been annualized against the most applicable time period for each Solution Cost. Annualization is most relevant for the Solution Costs to water scarcity because large infrastructure projects such as dams may be annualized by as many as 50 years, depending on the scale of the project.

Only a single Estimated Cost has been developed for each country or major basin, even though the cost of delivering sustainable water management varies based on the pathway or suite of Solution Costs used. Using a single Estimated Cost may overrepresent the precision of the global results. For discussion on the precision, accuracy, and calculation methods of Estimated Costs, see Appendix A.

Results

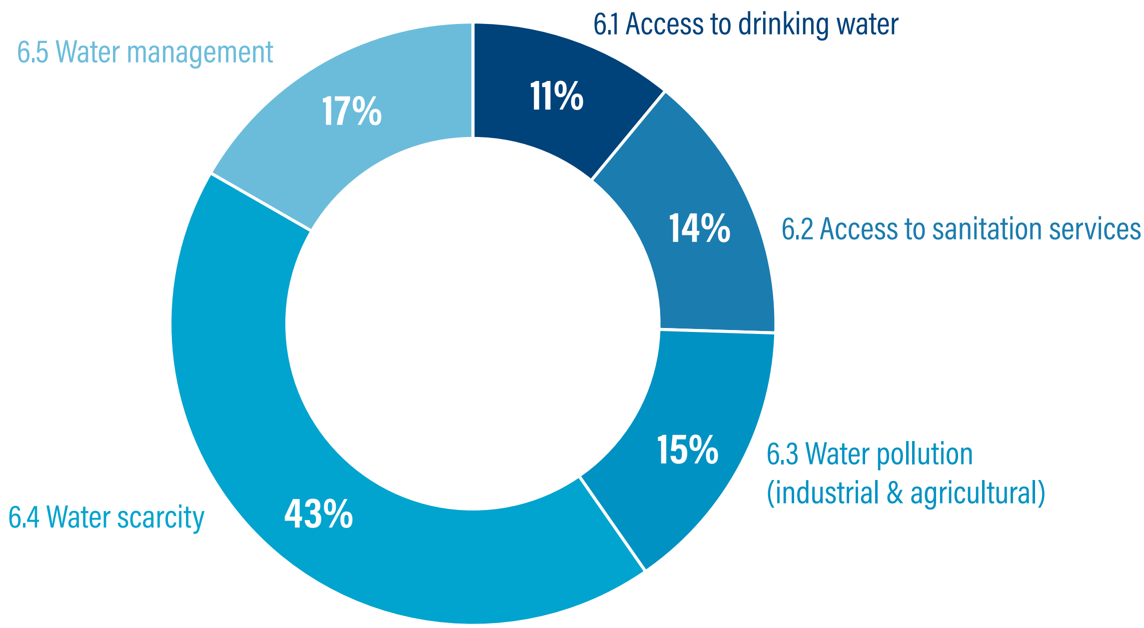
- The Global Estimated Cost of delivering sustainable water management is approximately $1.04 trillion (2015$) annually. The largest drivers of this cost are increased direct and indirect water demand associated with population growth and decreasing availability of water resources.
- Globally, addressing water scarcity is the largest component of Estimated Cost, totaling $445 billion (2015$) annually due to the magnitude of the issue and the relatively higher Solution Costs associated with resolving water scarcity challenges (Table 1). The most cost-effective solutions to water scarcity exist on the demand side rather than the supply side, and this Estimated Cost incorporates a suite of demand management and supply solutions based on the relevance of solutions within the geographic context (see Appendix A).
- With a 2018 global GDP of $85.79 trillion, delivering sustainable water management would only require about 1.21 percent of global GDP directed towards water resources (World Bank 2018).

Table 1 | **Estimated Cost to Deliver Sustainable Water Management Globally**

WATER CHALLENGE	ESTIMATED COST (US$, BILLIONS)
Total Estimated Cost	1,037
Access to drinking water	113
Access to sanitation services	150
Water pollution (industrial & agricultural)	153
Water scarcity	445
Water management	172

Note: All costs in 2015$ annually. Numbers may not add up due to rounding.
Source: WRI authors.

Figure 4 | **Global Breakdown of Estimated Costs**



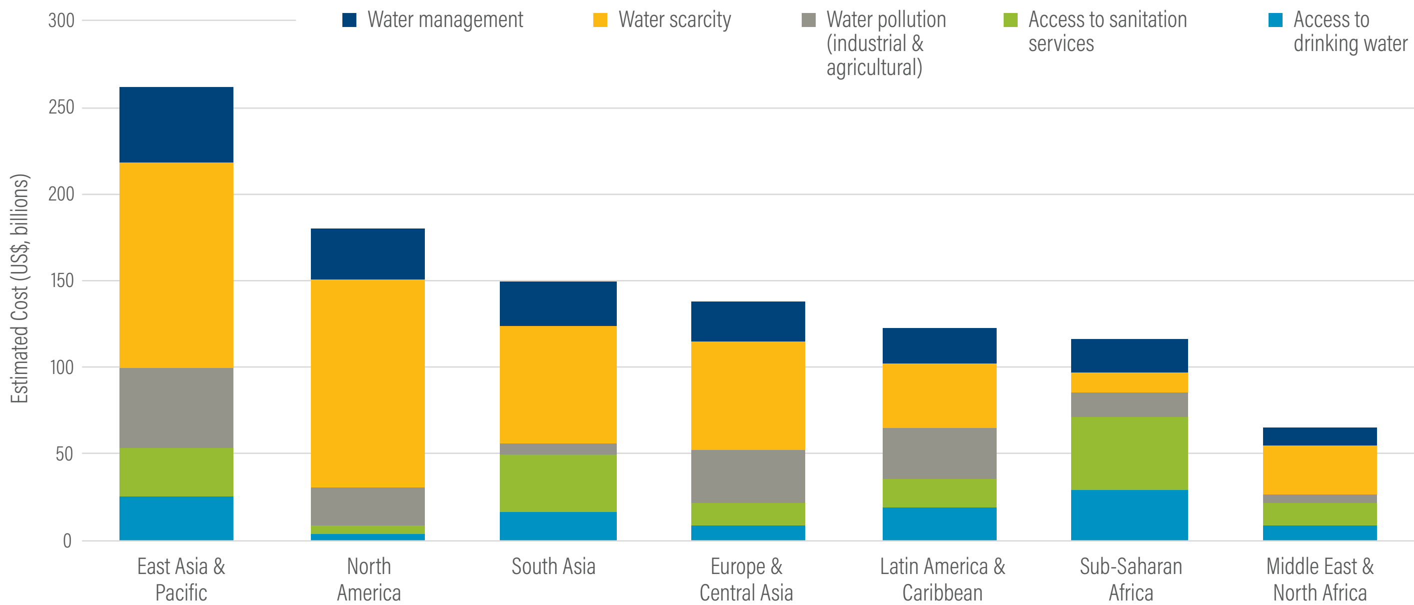
Source: Authors.

Water scarcity represents 43 percent of the total annual Global Estimated Cost (Figure 4), indicating that on a global scale, water resource availability and rising demand are the most expensive water challenges to resolve. However, the other Estimated Costs evenly account for the remaining 57 percent of needed costs, suggesting that no water challenge is negligible on the global stage.

The Estimated Costs of delivering sustainable water management vary by region, as do the most significant water challenges. Figure 5 shows the Estimated Cost of delivering all calculated aspects of sustainable water management, grouped by World Bank region. Absolute costs provide an understanding of the magnitude of different water challenges across geographies and indicate the degree of financing that needs to be directed towards varied water challenges. Several trends stand out within this regional breakdown:

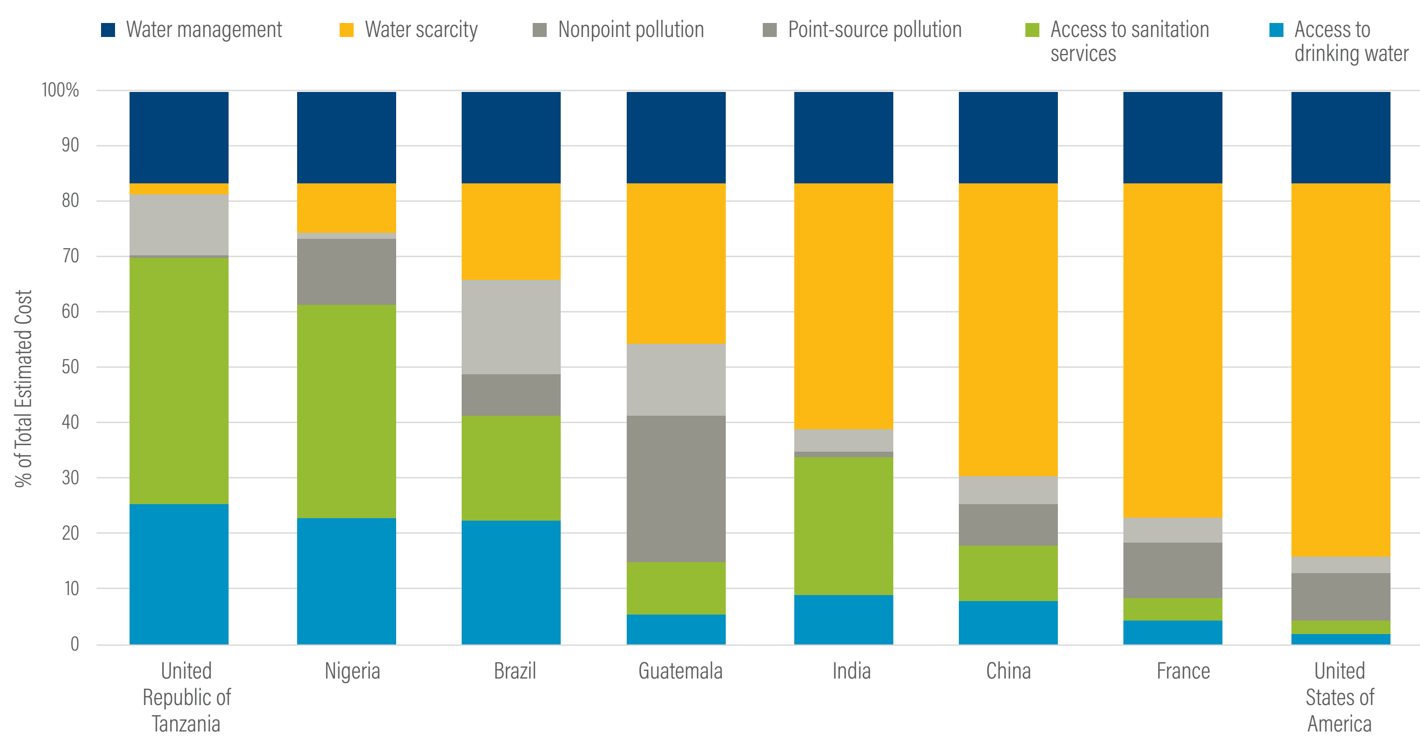
- Water scarcity may be the largest overall cost driver globally, but Estimated Costs to address water scarcity are largest in North America and in East Asia and the Pacific. Relatively speaking, sub-Saharan Africa and Latin America and the Caribbean have lower water scarcity Estimated Costs.
- East Asia and the Pacific, Europe and Central Asia, and Latin America and the Caribbean have disproportionately high costs to resolve industrial and agricultural water pollution sources. In South Asia and in the Middle East and North Africa, industrial and agricultural pollution represent only a small fraction of the Total Estimated Cost to deliver sustainable water management.
- The Estimated Costs to deliver access to drinking water and sanitation services are highest in sub-Saharan Africa, South Asia, and Latin America and the Caribbean. In North America and in Europe and Central Asia, these types of Estimated Costs are minimal relative to other water challenges.

Figure 5 | Estimated Costs by Region



Source: Authors; regions defined by World Bank (n.d.b).

Figure 6 | Normalized Country Estimated Costs for All Projected Gaps for Eight Sample Countries



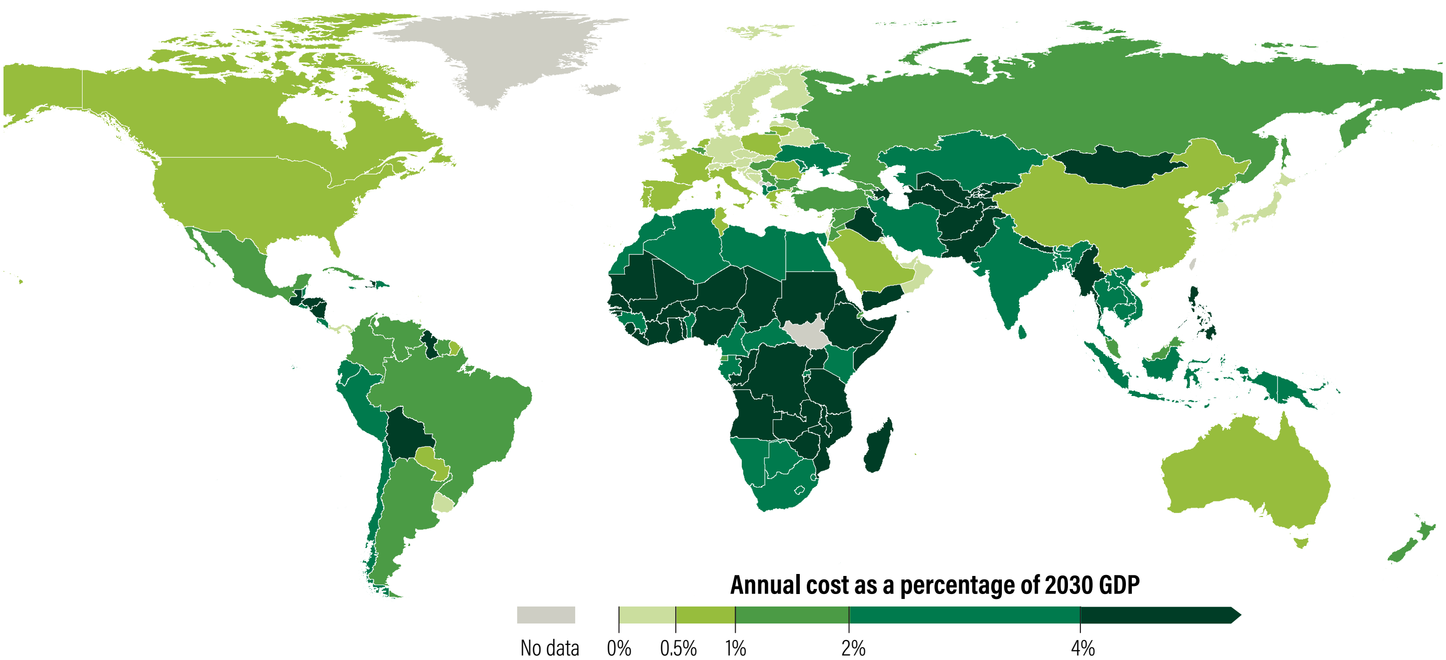
Source: Authors.

A similar geographic analysis can be performed by normalizing Estimated Costs between countries. Figure 6 shows the normalized Estimated Costs for eight sample countries, showing individual Estimated Costs as a percentage of the country's Total Estimated Cost. Normalized costs offer less information on the financial costs of water challenges for geographies, though normalized Estimated Costs make it easier to compare water challenges across geographies.[4]

- In the United States, France, China, and India, water scarcity is the primary driver of costs, from a cost perspective, limiting sustainable water management. India and China have costs associated with insufficient access to drinking water and sanitation services, whereas the United States and France have higher industrial pollution costs.
- Tanzania and Nigeria have high WASH-related costs—totaling 60–70 percent of all costs needed to achieve sustainable water management. In these countries, water scarcity is a small cost driver, as are water pollution costs.
- In Brazil and Guatemala, sources of water pollution are major cost drivers. Brazil has the highest non-point source pollution costs (as a percentage of Total Estimated Cost) of all the sample countries, whereas Guatemala has the highest industrial pollution costs. Both countries have water scarcity costs, but water quality appears to be the dominant water-related issue, especially if access to sanitation is categorized as a water pollution issue.

Country-level and regional data allow for simple comparison of water challenges across geographies. Decision-makers can use both the absolute and normalized Estimated Costs to support a range of macro-level activities, including investment prioritization, risk screening, identification of collective action opportunities, and support for multi-stakeholder discussions.

Figure 7 | **National Estimated Costs as a Percentage of 2030 National GDP**



Source: Authors; projected 2030 GDP from van Vuuren et al. (2007).

Global Estimated Costs also provide insight when combined with alternative sources of data, such as GDP or population. A Global Estimated Cost of $1.04 trillion (2015$) annually represents 1.21 percent of 2018 global GDP. Devoting just over 1 percent of GDP to delivering sustainable water management is ambitious but still achievable. However, these costs are not evenly distributed geographically, and some countries would need to devote far more than 1 percent of GDP to resolve water challenges. Figure 7 shows the variability of Estimated Costs with respect to (estimated 2030) national GDP.

For countries with a high national GDP—such as the United States, China, and European countries—the Estimated Cost of delivering sustainable water management represents less than 1 percent of national GDP. Countries with an Estimated Cost under 1 percent of their national GDP account for 43 percent of the Global Estimated Cost. For other regions, such as sub-Saharan Africa, the Middle East and North Africa, and South Asia, the Estimated Costs can exceed 2 or even 4 percent of national GDP. In these countries, delivering sustainable water management will require more financial resources.

Combining the Total Estimated Cost with national GDP or population (Table 2) is another way to compare and prioritize geographies. Of the eight sample countries, Tanzania, Nigeria, and Guatemala all have Total Estimated Costs that exceed 5 percent of national GDP. This means that in these countries, delivering sustainable water management would require significant mobilization of national resources or other financial investment. China, France, and the United States only need to invest under 1 percent of national GDP, although the absolute Total Estimated Costs are still quite high. From the perspective of cost per capita, however, the United States and Guatemala have much higher costs than other countries at $549 and $338 per capita, respectively.

There are numerous applications for these normalized figures, but at a macro level these results allow Estimated Costs to be compared between countries. These figures refer to the Total Estimated Cost for each country but could easily be broken down for each specific shared water challenge to make different comparisons and assessments. This paper does not seek to be prescriptive in applications of the Global Estimated Costs for decision-makers, but some possibilities are outlined in its conclusion.

Table 2 | **Sample Countries' Total Estimated Costs**

COUNTRY	TOTAL ESTIMATED COST (US$, BILLIONS, IN 2015$)	ESTIMATED COST PER PERSON (US$/CAPITA)	% OF ESTIMATED 2030 NATIONAL GDP
United Republic of Tanzania	4.5	100	6.0
Nigeria	28.1	179	5.0
Brazil	28.5	148	1.3
Guatemala	4.8	338	6.6
India	109.2	90	3.2
China	160.9	121	0.8
France	17.2	273	0.7
United States of America	168.4	549	0.8

Source: Authors; projected 2030 GDP from van Vuuren et al. (2007).

Interpretation

The Global Estimated Costs are intended to highlight major trends regarding the state of water resources. The Estimated Costs offer a glance at the magnitude of the challenge ahead with respect to delivering global sustainable water management. However, due to limitations in data quality and calculation methods, the strengths and weaknesses of the Estimated Costs must be clarified.

The strength of the Global Estimated Costs presented in this paper include the following:

- **Geographic comparability.** Estimated Costs are developed through a common method using global data that allows for geographic comparability.
- **Comprehensiveness.** The common method for different types of Estimated Costs and the single, comparable output metric allow for a comprehensive and comparable assessment of global water challenges.
- **Global coverage.** Estimated Costs are developed with global coverage at the country and basin scales.

These are some of the limitations of the Global Estimated Costs presented in this paper:

- **Resolution.** The data resolution for Estimated Costs is not fine enough to inform local decisions. Nations that are small or have a unique hydrologic or socioeconomic situation may not benefit from these estimates. Island nations, which are frequently small and poorly represented in global hydrologic models, should be particularly wary of using these results for national decision-making. Further, the scale of Estimated Costs (catchment, basin, national) has major trade-offs for the suitability of Estimated Costs for decision-making. Estimated Costs at the national level will not be optimal for use at the catchment level and vice versa.
- **Simplification.** Significant assumptions and simplifications were required to create global estimates, and many Solution Costs lack a robust geospatial component. Therefore, results serve better as directional signals than forecasts about the global cost to deliver sustainable water management.
- **Gaps.** Although the Estimated Costs cover many aspects of sustainable water management, some water-related issues—such as flood risk, existing debt, or land-use conservation—are not covered.
- **Single pathway.** The global results build off a hypothetical (albeit reasonable) set of Solution Costs to deliver sustainable water management by 2030. However, the input Solution Costs are only one pathway to achieving this goal—other paths may be more realistic or practical and have different costs.

The greatest strength of the Global Estimated Costs, the authors believe, is that they fill a literature gap by providing the first comprehensive estimate of costs at the global scale. However, this paper builds on a collection of literature and recognizes that a wide range of methods, tools, frameworks, and approaches have been developed to help deliver sustainable water management; much of this preexisting work is more suitable for informing local decisions than is this paper. Further, many global costs for achieving specific components of sustainable water management or SDG 6 targets already exist and offer useful benchmarking for this paper's global results (Table 3).

Table 3 | **Additional Relevant Literature and Cost Estimates**

DESCRIPTION	COST ESTIMATE (US$, BILLIONS)	SOURCE
Cost to deliver water access to urban and rural populations in 140 countries	64–134	Hutton and Varughese 2016
Cost to deliver sanitation services to urban and rural populations in 140 countries	70–106	Hutton and Varughese 2016
Investment to accomplish a 10% reduction in sediment and nutrient loading in water bodies	42–48	Abell et al. 2017
Expected incremental capital investment to close the water resource availability gap by 2030, if done in the least costly way available	50–60	2030 WRG 2009
To achieve full operations and maintenance for water and sanitation, wastewater collection and treatment, and related water resources development in Brazil, Russia, India, China, and South Africa	500–1,037	Winpenny 2015

5. CONCLUSION

This paper seeks to provide a standard approach to assessing the cost delivering sustainable water management and a global data set of Estimated Costs. The Global Estimated Costs are most useful for macro-level analysis, strategic comparison, and identifying locations or strategies for further analysis. The Proposed Approach is designed for decision-makers to follow with the most relevant local data. A two-step approach—that is, using the global results for initial estimates and then substituting more granular data to meet more specific objectives—may prove to be the best application of this work.

This paper does not seek to be prescriptive, and the Proposed Approach or global results may be used by a wide variety of decision-makers, including national governments, multilateral development banks, financial service providers, international companies, and river basin authorities. Without being exhaustive, the paper offers applications for both outputs for select public and private sector decision-makers.

Applications: Global Results

1. **Multilateral development banks or financial institutions** can use the global results as data to support activities such as screening loans, financing priorities or opportunities, and tracking activities to meet SDG 6.

2. **International companies and financial institutions** can use the global results to inform operations portfolios or supply chain risk assessment, future site screening, and water stewardship activity planning. These decision-makers can also use the global results to inform capital allocation to water management priorities across their portfolio.

3. **National governments or regional river basin authorities** can use the Global Estimated Costs to assess national water management priorities and tracking activities to meet SDG 6.

4. **Any decision-maker** can supply multistakeholder platforms with Estimated Costs as a starting point for discussion and consensus among other stakeholders.

Applications: Proposed Approach

1. **National or local governments** can follow the Proposed Approach and input local data to assess and improve local water management priorities.

2. **Governments or utilities** can follow the Proposed Approach using local data and use the output to inform local financing needs.

This Working Paper seeks to progress our understanding of the cost of delivering sustainable water management to drive more effective resolution of water resource challenges. The Proposed Approach and Estimated Costs are a first attempt at this task and are expected be refined in response to evolving ideas and information. Further research is required to improve the accuracy, comprehensiveness, spatial resolution, and applicability of the Estimated Costs and Proposed Approach. However, the authors intend this paper to be a useful starting point for understanding the costs of delivering sustainable water management.

APPENDIX A: METADATA, RESULTS, AND LIMITATIONS

This appendix documents the data inputs, calculation methods, and assumptions and limitations behind the Global Estimated Costs. The provided scale is for countries and major basins (WRI 2015; FAO GeoNetwork 2015). The purpose of the appendix is twofold:

- For decision-makers using the Estimated Costs, to document the necessary information to ensure a full understanding of the assumptions and implications embedded in the Estimated Costs.
- For decision-makers using the Proposed Approach, to illustrate how the approach can be translated from a theoretical framework into a useful output.

The global results calculated Estimated Costs for the following aspects of sustainable water management, according to the framework outlined in SDG 6:

- The cost to achieve universal access to drinking water.
- The cost to achieve universal access to sanitation and basic hygiene and to eliminate open defecation.
- The cost to treat all industrial wastewater discharge to tertiary treatment standards.
- The cost to reduce agricultural nutrient pollution to achieve acceptable concentrations of nutrients in water bodies.
- The cost to eliminate water scarcity by reducing the ratio of water demand (human and environmental) to renewable water supply to within acceptable boundaries.
- The cost to increase regulation and management of water resources in line with the need to manage other water-related investments.

For each of these water-related challenges, this appendix provides

- an overview of the relevant definitions;
- the data used to generate the Projected Gap;
- the data used to generate the Solution Costs;
- the limitations and assumptions inherent in the calculation method and data inputs and outputs;
- a detailed breakdown of results for the respective water challenge; and
- a review of similar literature or cost estimates and the main method differences.

The accuracy and precision of the data inputs for the Projected Gaps and Solution Costs largely determine the robustness of the calculation method and Estimated Cost. To indicate the quality of Projected Gaps, Solution Costs, and Estimated Costs, this appendix provides a confidence interval for each respective calculation (Table A1). Rather than provide cost ranges, which can result in major uncertainty regarding the meaning and implications of Estimated Costs, the authors rely on the confidence interval to signal the robustness of the generated Estimated Costs.

Table A1 | **Confidence Interval Evaluation Criteria**

CONFIDENCE INTERVAL	EVALUATION CRITERIA
Low	■ There is no robust geospatial component to the data. ■ The input data contain information that does not fully represent the challenge or solution. ■ The calculation method relies on major assumptions. ■ The calculation method has not been attempted before.
Medium	■ There is a partial but incomplete geospatial component to the data. ■ The input data contain a moderate range of information that is partially representative of the challenge or solution. ■ The calculation method relies on minor assumptions. ■ The calculation method modifies a known and documented approach.
High	■ There is a robust geospatial component to the data. ■ The input data contain a large range of information that represents the challenge or solution. ■ The calculation method and assumptions follow an understood and documented approach.

Source: Authors.

SDG 6.1 and SDG 6.2: Water Access, Sanitation, and Hygiene Services

SDG 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

SDG 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

SDG 6.1 and SDG 6.2, which consider WASH, have clear definitions of terminology. For SDG 6.1, the World Health Organization (WHO) defines safely managed drinking water as either "accessible on premise" or "available when needed" and "free from contamination" (WHO and UNICEF 2017). For SDG 6.2, WHO defines safely managed sanitation as either "emptied and treated" facilities, "disposed of in situ," or "transported to and treated at a facility" (WHO and UNICEF 2017). Achieving SDG 6.2 also requires full access to "handwashing facilities with soap and water at home" and elimination of open defecation practices (WHO and UNICEF 2017).

Each Estimated Cost was calculated independently for five different Projected Gaps, one for each WASH service. These Projected Gaps are populations that lack access to safely managed drinking water, safely managed sanitation, basic sanitation, and basic hygiene as well as those that practice open defecation.

Projected Gap

For SDG 6.1 and SDG 6.2, the gap is the population in 2030 without access to a given WASH-related service. This paper used the following sources to calculate these population gaps for each country:

- Country-level information on urban and rural populations with access to different WASH services (WHO and UNICEF 2017; Hutton and Varughese 2016)
- Current and future geospatial population distribution (van Vuuren et al. 2007) for both urban and rural populations—that is, urban extents (van Huijstee et al. 2018)

Combining the data sets using Hutton and Varughese's methodology (Equation A1) yielded country-by-country urban and rural populations in 2030 without access to a given WASH service.

Equation A1:

$$\boldsymbol{Projected\ gap =}$$
$$\mathbf{2030}\ \boldsymbol{population} - (\mathbf{2010}\ \boldsymbol{population} * \mathbf{2010}\ \boldsymbol{access\ rate})$$

Solution Costs

For SDG 6.1 and SDG 6.2, the Solution Costs are the cost per person to deliver a given type of WASH service. For access to drinking water (SDG 6.1), these costs include providing safely managed drinking water to the unserved population. The Solution Costs include capital investment, delivery, operations costs, and major capital maintenance projects necessary to deploy and sustain the infrastructure required to deliver safely managed drinking water (Hutton and Varughese 2016).

For SDG 6.2, the Solution Costs are the cost of providing safely managed sanitation facilities[5] as well as those to deliver basic access to handwashing facilities and eliminate open defecation practices for all unserved populations. These costs include capital investment, delivery, and operations for extraction, treatment, conveyance, and disposal as well as major capital maintenance projects necessary to deploy and sustain the infrastructure required for safely managed sanitation, basic handwashing facilities, and eliminating open defecation (Hutton and Varughese 2016).

Data for all country-by-country Solution Costs, urban or rural, were drawn from Hutton and Varughese (2016). Hutton and Varughese, however, only offer Solution Costs for 140 lower-income countries; thus, where no solutions were available, a country's urban or rural Solution Costs were extrapolated from countries in a similar region and with similar income levels (World Bank, n.d.b).

Estimated Costs

The Estimated Costs for SDG 6.1 and 6.2 were calculated by multiplying the number of people in need of the WASH service by the respective cost per person. Specifically, SDG 6.1's Estimated Cost includes safely managed drinking water for urban and rural communities; SDG 6.2's Estimated Cost includes safely managed sanitation (i.e., treatment), basic sanitation (i.e., infrastructure), hygiene, and an end to open defecation for urban and rural communities.

The Estimated Costs were originally calculated at the country scale. The results were disaggregated to the major river basin scale using 2030 gridded population data (van Vuuren et al. 2007) following the methodology presented by Gassert et al. (2013).

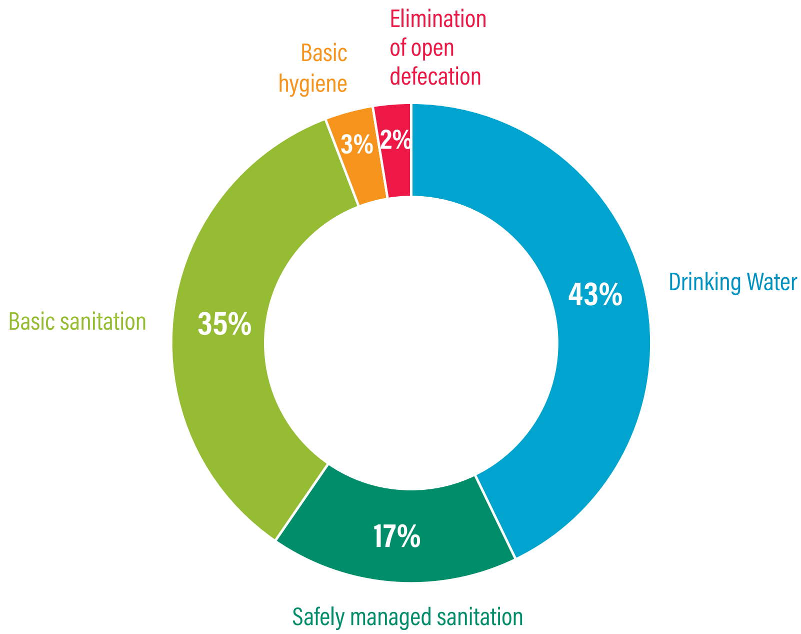
Results

This study estimates the global annual investment to cover all WASH-related services by 2030 at $264 billion. This accounts for 25 percent of global investment to meet SDG 6 overall, with SDG 6.1 and SDG 6.2 requiring 11 percent and 14 percent of total SDG 6 investment, respectively.
Providing access to drinking water accounts for $114 billion (43 percent of WASH-related costs), followed by providing basic sanitation ($91 billion, or 34 percent) and safely managed sanitation ($44 billion, or 17 percent).

The cost to deliver WASH-related services is highly variable, with projected population growth and current access rates as the major driving factors. The countries with the highest absolute WASH-related Estimated Costs—India, China, Nigeria, Brazil, Mexico, Ethiopia, and the United States—are also the countries with high projected population growth (see Figure A1).

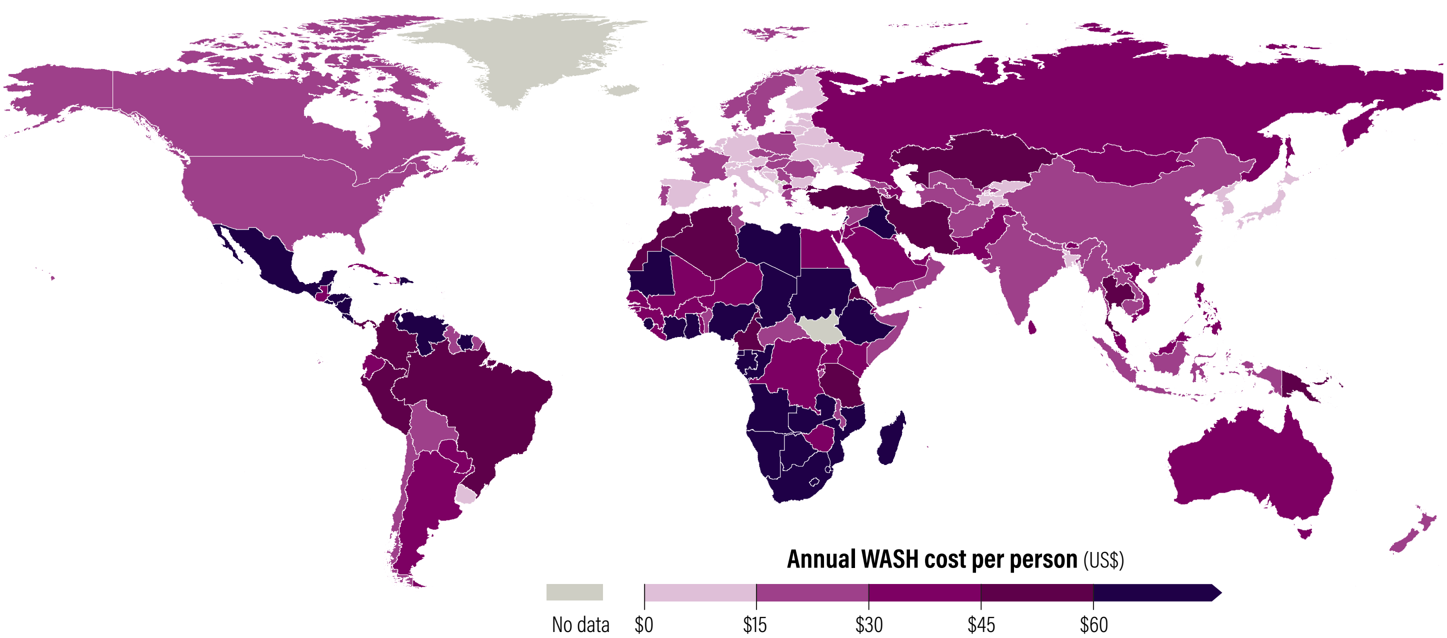
If broken down on a cost per capita basis, though, most countries fall between $7 and $23 per person to deliver SDG 6.1 and slightly more to deliver SDG 6.2. Figure A2 shows the distribution of WASH investments per capita, with the largest per capita investments in Africa, the Middle East, and Central America, also in alignment with other estimates (WHO and UNICEF 2017; Hutton and Varughese 2016). These locations with the highest per capita investment are also those where achieving SDG 6.1 and SDG 6.2 account for the largest percentage of national GDP. The median national GDP expenditure for countries on SDG 6.1 and SDG 6.2 is 0.32 percent, although WASH-related expenditure varies greatly based on current access rates, population growth, and projected 2030 national GDP.

Figure A1 | **Global Breakdown of WASH Services' Estimated Costs**



Note: Breakdown shows the percentage of the Total Estimated Cost for WASH, which is roughly $264 billion.
Source: Authors.

Figure A2 | **Cost of WASH Services Per Capita through 2030**



Source: Authors.

The estimate of $264 billion per year to cover all WASH-related investments lines up with other estimates. For example, Hutton and Varughese (2016) estimate an average of $114 billion annually to achieve SDG 6.1 and SDG 6.2. This study's cost estimates were calculated using a similar method and using Hutton and Varughese's costs per country to deliver WASH services to urban and rural populations. The higher estimates from the more recent method are driven by different population predictions, urbanization expectations, and for delivering WASH-related services globally, whereas Hutton and Varughese look at 140 lower-income countries. The inclusion of global North countries with high population growth (such as the United States) drives up all costs. Although these countries already have high levels of access to drinking water and sanitation services, the expected population growth of global North countries—and the respective burden on existing infrastructure—will require additional investment in WASH-related infrastructure through 2030.

SDG 6.1 and SDG 6.2 Comparable Cost Estimates (US$, billions)

TOTAL COST	DRINKING WATER	SAFELY MANAGED SANITATION	BASIC SANITATION	HYGIENE	ELIMINATION OF OPEN DEFECATION	ALL WASH
This assessment	114	92	45	9	7	264
Hutton and Varughese 2016	65–134	38–77	9–33	2–3	3–4	74–166

Discussion

The WASH-related SDG 6 Estimated Costs calculations are robust relative to other SDG 6 investment calculations. The access to high-quality geospatial projections of urban and rural populations—as well as country-by-country estimates of the cost to deliver WASH-services to urban and rural populations—allows for reasonably high confidence in the final outputs relative to other SDG 6 Estimated Costs. Even so, there are important limitations, including the following:

- Service access rates are determined on a national basis and are applied to all urban and rural populations within a country. The extrapolation of country data to specific urban and rural locations assumes that all urban and rural populations have the same access rates.
- This paper assumes that current treatment and distribution infrastructure is operating at maximum capacity and is already suitably financed. Assuming infrastructure is already operating at maximum capacity likely overestimates WASH-related service costs. However, assuming current infrastructure is suitably financed underestimates WASH-related service costs—there are operations and maintenance costs for existing treatment and distribution systems that are not accounted for in this paper.
- Each country assesses service access rates through different methods, but in this study the access rates for urban and rural populations (drawn from Hutton and Varughese 2016) are assumed to be fully comparable.
- Hutton and Varughese (2016) only assessed 140 lower-income countries. All costs were drawn from this source; where no costs were provided, this paper extrapolated costs based on countries with similar income levels. This approach assumes that countries at the same income level require the same investment per capita to deliver services.

Confidence Interval: SDG 6.1 and SDG 6.2, WASH

	DRINKING WATER	SAFELY MANAGED SANITATION	BASIC SANITATION	BASIC HYGIENE	ELIMINATION OF OPEN DEFECATION
Projected Gap	High	High	High	High	High
Solution Cost	High	High	High	High	High
Estimated Cost	High	High	High	High	High

Source: Authors.

SDG 6.3: Water Pollution (Industrial)

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

SDG 6.3 focuses on the domestic and industrial aspects of water pollution. Domestic water pollution is assumed to be covered as part of the Estimated Cost to deliver safely managed sanitation services (SDG 6.2); this calculation method focuses solely on industrial wastewater.

The target calls for "eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater" (World Bank 2015). This paper has changed the specificity of this target. The desired end state is defined as treating all industrial point source pollution to tertiary treatment levels. Tertiary treatment levels are assumed to eliminate dumping and the release of hazardous chemicals and exceeds the requirement to halve untreated wastewater.

Projected Gap

The Projected Gap is the volume of untreated industrial wastewater in 2030 per country. To estimate the Projected Gap, this calculation uses data on

- industrial water withdrawals and return flows, to identify the amount of industrial wastewater entering water bodies in 2010 and 2030 (Gassert et al. 2015; Luck et al. 2015); and
- country-level statistics on connection rates and wastewater treatment rates (Xie et al. 2016).

Combining the data sets using Equation A2 yielded country-by-country estimated wastewater return flows in 2030 for wastewater in need of secondary and tertiary treatment.

Equation A2:

$$\begin{gathered} Projected\ gap = \\ 2030\ return\ flow - \\ (2010\ return\ flow * 2010\ connected\ treatment\ rate) \end{gathered}$$

Solution Costs

The Solution Costs are the cost to treat industrial wastewater to secondary and tertiary treatment standards. The cost per m^3 was derived from

- existing country-level estimates to treat urban and rural wastewater to secondary treatment levels (Hutton and Varughese 2016); and
- a uniform cost function (Equation A3) that estimated the cost of applying tertiary treatment to wastewater already undergoing secondary treatment (Hernández-Sancho et al. 2011). We ran the function using an 80 percent removal efficiency rate for chemical oxygen demand, nitrogen, and phosphorus (Directorate-General for Environment 2003).

Equation A3:

$$C_t = 3.7732\ x\ \left(\frac{PG_t}{15\ years}\right)^{0.7223} x\ e^{(0.6721COD+0.01958N+0.7603P)}$$

in which,
C_t = annual cost for tertiary treatment ($/year)
PG_t = Projected Gap in tertiary treatment of wastewater ($m^{3)}$
COD = chemical oxygen demand removal efficiency (%)
N = nitrogen removal efficiency (%)
P = phosphorus removal efficiency (%)

Combined, these data sets yielded country-specific costs to treat industrial wastewater to secondary treatment levels and then a nongeospatial cost to treat industrial wastewater to tertiary levels.

Estimated Cost

The Solution Cost estimates were applied to the respective volume of untreated and partially treated industrial wastewater—the Projected Gap—to estimate the total cost of treating industrial wastewater to tertiary treatment levels. We applied PPP factor to the costs of tertiary treatment to make the results more spatially relevant.

The Estimated Costs were originally calculated at the country scale. The results were disaggregated to the major river basin scale using 2030 gridded industrial withdrawal data (Gassert et al. 2015) following the methodology presented by Gassert et al. (2013).

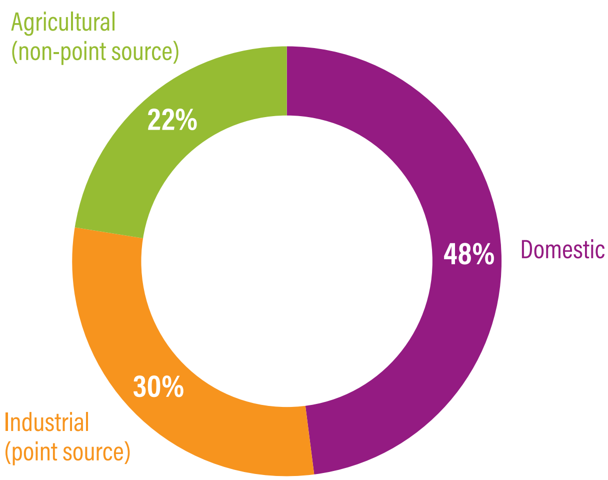
Results

- Industrial pollution Estimated Cost total $87 billion, accounting for 30 percent of pollution costs overall (Figure A3).
- Addressing domestic, industrial, and agricultural aspects of water pollution requires an estimated annual investment of $297 billion.

The drivers of water pollution costs are varied, meaning water pollution costs are generally more distributed between countries. However, there is still high variation in costs between countries overall—the top 10 countries account for about 52 percent of global water pollution costs (see Figure A4). Domestic water pollution is driven by population growth, with the highest Estimated Costs in countries with high anticipated growth: India, China, Nigeria, Ethiopia, Brazil, and the United States. See the discussion on SDG 6.2 for more details.

Industrial water pollution accounts for 30 percent of water pollution investments, totaling $97.4 billion annually. Industrial pollution is primarily driven by GDP growth. The United States, China, and Russia emerge as the highest sources of industrial pollution. However, industrial pollution costs have a lower variation between countries compared to other sources of pollution; industrial pollution is distributed widely across all countries, unlike other SDG 6 investments. Median country investment per capita (2030) is $4.54 per person to fully treat industrial wastewater, with an interquartile range of $1.37–$16.48 per person.

Figure A3 | Global Breakdown of Water Pollution Estimated Costs



Note: Domestic point source pollution overlaps with SDG 6.2 but is shown here in relation to industrial and agricultural pollution costs due to the relevance of SDG 6.2 in achieving healthy water quality and eliminating untreated wastewater.
Source: Authors.

Comparing the estimated $87.4 billion required for industrial wastewater treatment against other assessments is complex because many assessments look at required investment in treatment infrastructure regardless of the sector receiving the service. However, some assessments of wastewater treatment infrastructure allow for general comparison:

- To achieve full operations and maintenance for water and sanitation, wastewater collection and treatment, and related water resources development, an estimated $1.037 trillion annually is required by 2025 (OECD 2006). This assessment is only for the Organisation for Economic Co-operation and Development (OECD) and Brazil, Russia, India, China, and South Africa, and it is based on historic national GDP expenditure percentages towards the water sector, with different development categories for countries.

Confidence Interval: SDG 6.3

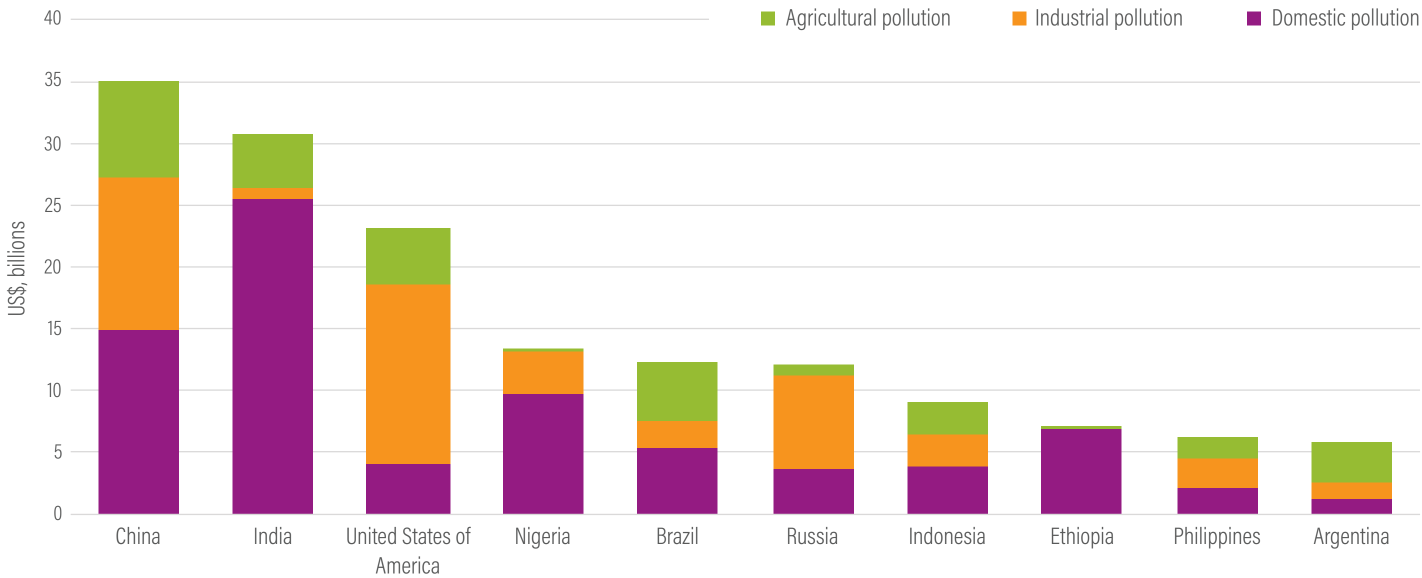
	INDUSTRIAL
Projected Gap	Low
Solution Costs	Medium
Estimated Cost	Medium

Source: Authors.

Discussion

- The cost to achieve secondary treatment of wastewater is derived from Hutton and Varughese (2016), assuming that secondary treatment costs do not differ between domestic and industrial wastewater treatment.
- This paper lacked geospatial data on the rate of connection to treatment plants and existing treatment levels for industrial facilities. It assumed that the industrial connection rate was equal to the household connection rate to sewerage systems of each respective country.
- The cost to treat wastewater from secondary to tertiary treatment levels was based on a single cost-function from Hernández-Sancho et al. (2011). This cost was derived from data from wastewater treatment plants in the European Union and may not fully represent the cost of tertiary treatment for all countries. PPP has been considered to accommodate for the lack of geospatial data (World Bank 2018).

Figure A4 | **Top 10 Country Water Pollution Estimated Costs**



Note: Due to different pollution drivers, global South and global North countries tend to have different water pollution profiles in terms of sector.
Source: Authors.

SDG 6.3: Water Pollution (Agricultural)

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

Agricultural nutrient pollution is not explicitly called out under SDG 6.3. However, agricultural nutrient leaching is a major factor in water pollution and is therefore considered in this paper. Without a specific SDG 6 target, this paper sets the desired end state as the full reduction of agricultural sources of nitrogen and phosphorus to acceptable concentrations in all water bodies by applying agricultural best management practices (BMPs) for nutrient reduction. This definition requires several clarifications:

- Agricultural sources of nitrogen and phosphorus exclude domestic and industrial nutrient sources as well as nonanthropogenic sources.
- *Acceptable concentration is the maximum allowable concentration for nitrogen and phosphorus in a water body (e.g., mg/L) before the basin can no longer assimilate nutrients (see Table A2).*
- Agricultural BMPs for nutrient reduction are practices common on farmland or grazing land to reduce nutrient leaching; for example, buffer zones of manure management.
- This definition does not account for freshwater or coastal eutrophication. Instead, it assumes the elimination of excess nutrients from agricultural sources would resolve eutrophication issues in combination with the elimination of domestic and industrial wastewater.

Projected Gap

The Projected Gap is the total pounds of nitrogen or phosphorus from agricultural sources that need to be removed from water bodies to reduce nutrient loading to the acceptable concentration. To identify the nutrient loading required to be reduced, the Projected Gap calculation pulled from the following data sources:

- Global nitrogen and phosphorus loading in water bodies in 2030 (Bouwman et al. 2015)
- Projected 2030 available blue water in water bodies (Luck et al. 2015)
- Natural and maximum nutrient concentrations in water bodies (Mekonnen and Hoekstra 2015, 2018)

Table A2 | **Acceptable Levels of Concentration for Nitrogen and Phosphorus**

	NITROGEN[a]	PHOSPHORUS[b]
Natural (mg/L)	0.4	0.01
Maximum allowable (mg/L)	2.9	0.02

Sources: a. Mekonnen and Hoekstra 2015; b. Mekonnen and Hoekstra 2018.

To develop a final estimate of nutrients required to be removed from each water body, the water pollution level (WPL) method (based on the gray water footprint) was followed according to the steps originally laid out in Hoekstra and Mekonnen (2011) (with additional support found in Liu et al. 2012; Mekonnen and Hoekstra 2015, 2018). The WPL represents the ratio of nutrients assimilated by river runoff (Mekonnen and Hoekstra 2015). A WPL greater than one indicates that there are more nutrients than the runoff can manage. Therefore, the target WPL was set at one. For basins that exceeded this target, we calculated how many pounds of nutrient were required to be removed in order to reach a WPL of one.

Solution Cost

The Solution Cost is the cost to reduce a pound of nitrogen or phosphorus from a water body. This paper drew on a variety of literature[6] to create a weighted average cost per pound ($/lb) of removal for nitrogen and phosphorus. A summary of these costs and associated removal efficiencies are provided in Table A3. The cost to reduce a pound of nutrient was set at $5.61/lb of nitrogen removed or $11.21/lb of phosphorus removed.

Table A3 | **Overview of Best Management Practices**

PRACTICE	AVERAGE $/ LB NITROGEN REMOVED	NUTRIENT REMOVAL EFFICIENCY (%)
Animal waste management systems	2.77	33.57
Grazing/pasture management	5.41	10.05
Riparian forest buffers	6.21	20.52
Wetland restoration	6.87	16.75
Nutrient management	7.66	8.83
Conservation cover crops	10.20	17.39
Conservation tillage	10.48	13.50
Riparian grass buffers	11.71	20.52

Sources: Data drawn from Gachango et al. (2015), Hellsten et al. (2017), Jones et al. (2010), Lam et al. (2011), Webb et al. (2006), Liu et al. (2014), Oenema et al. (2009), and Vibart et al. (2015).

Estimated Cost

For each basin, the Estimated Cost was calculated by multiplying the pounds of nutrient to be removed (using whichever nutrient was farther above maximum concentrations) by the BMP cost. To add a geospatial component, the static removal rate was adjusted for local PPP (World Bank 2018).

The Estimated Costs were originally calculated at the country scale. The results were disaggregated to the major river basin scale using 2030 gridded crop and pastureland cover data (Ramankutty et al. 2008) following the methodology presented by Gassert et al. (2013).

Results

Nonpoint source pollution, or excessive nutrient loading from nitrogen and phosphorus, is estimated at a total of $66 billion annually—22 percent of the total water pollution costs. Specifically, this is the cost of applying agricultural BMPs to reduce agricultural sources of nitrogen and phosphorus loading below maximum acceptable concentrations. Due to the selection of natural and maximum concentrations, the variable driving cost in nearly all river basins was phosphorus. The median country costs per capita (2030) to achieve this reduction is $5.20 per person, with an interquartile range of $1.51–$14.08 per person. These agricultural costs are the lowest costs (per capita) for eliminating a specific sector's pollution problem; this is likely because the cost to apply agricultural BMPs tends to be lower than other types of wastewater treatment, particularly treatment that relies on gray water treatment infrastructure.

The Nature Conservancy estimates that to achieve a 10 percent reduction in nitrogen, phosphorus, and sediment in 90 percent of source watersheds for major cities around the world, $42–$48 billion would be needed annually (Abell et al. 2017). The estimate of $42–$48 billion for only 10 percent of nutrient reduction suggests that $66 billion to eliminate all agricultural nutrient pollution may be a low estimate; however, the orders of magnitude are the same.

Although similar numbers, the method behind these calculations differs greatly. Abell et al. (2017) identified a 10 percent reduction requirement in nutrients and sediment and calculated the application of BMPs based on land-use patterns within a basin. To contrast the land-use pattern approach, this study used a method based on reducing the maximum concentrations of nitrogen and phosphorus within water bodies to acceptable levels (Liu et al. 2012; Mekonnen and Hoekstra 2015, 2018).

Confidence Interval: SDG 6.3, Water Pollution

	AGRICULTURAL
Projected Gap	Low
Solution Costs	Low
Estimated Cost	Low

Source: Authors.

Discussion

- The presented estimates lacked a geospatial data set for the cost to remove a pound of nitrogen or phosphorus for global South countries. The cost of nutrient removal was set at a static removal rate ($5.61/lb of nitrogen removed or $11.21/lb of phosphorus removed), based on a literature review of nutrient removal costs from global North countries. This cost was adjusted for each country's PPP; however, the static number may overestimate costs outside the global North and ignore cost variations due to highly efficient (or inefficient) solutions to agricultural nutrient pollution.
- This paper drew on an existing method of identifying the extent of nutrient problems (Hoekstra and Mekonnen 2011; Liu et al. 2012; Mekonnen and Hoekstra 2015, 2018) based on natural and maximum concentrations of nitrogen and phosphorus in water bodies. As a result, the output is highly sensitive to the assumed natural and maximum concentrations. Further, these concentration assumptions are not geospatial—all rivers are assumed to have the same natural and maximum nutrient concentrations.
- The model's sensitivity to natural and maximum concentrations of nitrogen and phosphorus is very high, and due to the selected concentrations, phosphorus was determined to be the driving force in nearly all assessed basins.
- Using a water body's nutrient concentration capacity to identify the extent of nutrient removal needs does not account for land-use patterns within a country or basin. It is possible the application of the proposed agricultural BMPs is limited to less than the proposed amount due to existing land-use patterns.

SDG 6.4: Water Scarcity

SDG 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

This paper assumes the desired end state with respect to water scarcity is to bring all social, economic, and environmental uses of water in alignment with available water resources. This desired outcome is broader than simply reducing the number of people suffering from water scarcity, and it intentionally captures more dimensions of water scarcity than the social component highlighted in SDG 6.4.

The desired end state is to "bring human and environmental water demand within renewable available water volumes within a basin." This desired end state builds off the definition of baseline water stress, which "measures the ratio of total annual water withdrawals to total available annual renewable supply, accounting for upstream consumptive use" (Gassert et al. 2015).

Projected Gap

The supply-demand gap is calculated as the total gap between water availability and water demand annually at the catchment level, in m^3. The gap is calculated on a monthly basis, using the following:

- Monthly available water supply in 2030 was drawn from Aqueduct Water Risk Atlas projections (Luck et al. 2015).
- Monthly water demand per sector was drawn from 2030 withdrawals for the agricultural, industrial, and domestic sectors (Luck et al. 2015; Hofste et al. 2019).
- Monthly environmental flow requirements were calculated using monthly natural discharge (Luck et al. 2015) and the variable monthly flow method (Pastor et al. 2014).

Combined, these data sets yielded catchment-level gaps in water supply and demand. While this provides us with how much water should be "saved," we still need to identify where those savings should come from. Instead of using the blunt least-cost method for ascribing solutions, we designed an approach that both considers current sectoral efficiency investments and prioritizes an equitable distribution of costs. Therefore, our next step was to identify efficiency targets per sector. Due to data limitations, this was done per sector at the country scale using the data sets provided in Table A4. We combined these data with country sectoral withdrawals to create an efficiency rate; for example, the domestic efficiency rate is population per domestic withdrawal (population/m^3). For all sectors, we designated the 20th percentile as the target efficiency rate. For those countries not meeting the desired efficiency threshold (i.e., less efficient in water use), the sectoral efficiency gap was identified as the m^3 between current sector efficiency and desired sector efficiency.

Table A4 | **Data Sources Used to Create the Efficiency Measure for Each Sector**

SECTOR	EFFICIENCY MEASURE
Agricultural	2010 national GDP from agriculture
Industrial	2010 industrial value added
Domestic	2010 population

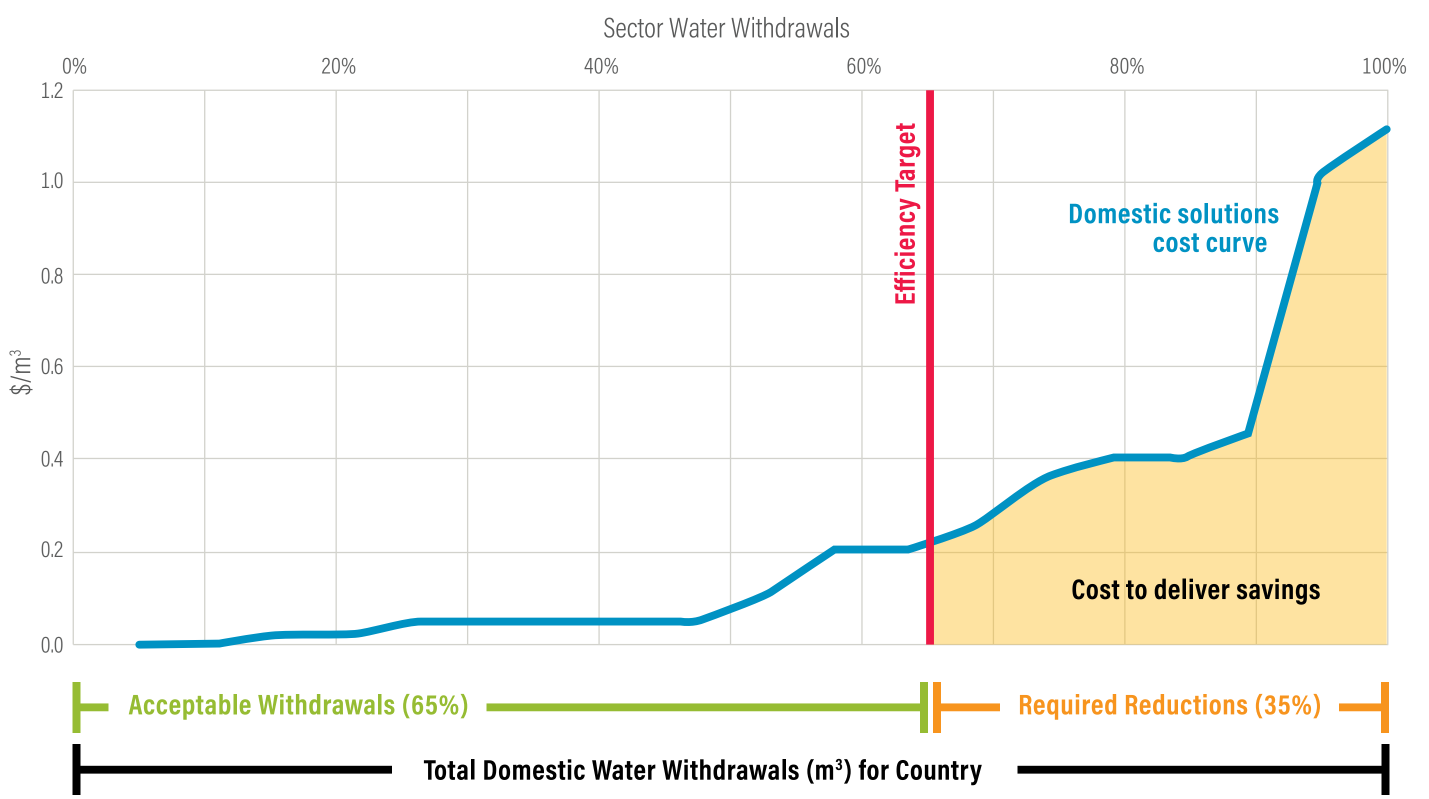
Sources: World Bank 2018; van Vuuren et al. 2007.

The country-level sectoral efficiency gaps were resampled to the catchment scale and used to allocate the supply-demand gap into sector-specific efficiency targets (percentage of sector withdrawal to be saved).

Solution Costs

For each sector, a list of cost curves was generated, ordering solutions from least cost to greatest costs. Sectors with cost curves are agricultural, domestic, industrial, and supply-side solutions. A suite of sector-specific and water supply Solution Cost curves was curated using the 2030 Water Resources Group (WRG) reports (2030 WRG 2009, 2012). Only solutions with a clear cost per m^3 are appropriate for this analysis. Each solution was provided through a local case study with a cost per m^3 and was linked to a sector. Generally, demand management solutions are more cost-effective than supply-side solutions, but all solution types are included in this analysis.

Figure A5 | **Cost Curve per Sector per Country**



Source: Authors.

Estimated Costs

Cost curves like the one illustrated by Figure A5 were used to find the Estimated Cost per sector. The Projected Gap (percentage of total sector withdrawal to be saved) was used to integrate the cost curve per sector. The final Estimated Cost is the sum of the cost to achieve agricultural, domestic, and industrial water savings as well as to add additional supply infrastructure when needed.

The Estimated Costs were originally calculated at the catchment scale. The results were aggregated to the major river basin and country scales using 2030 gridded withdrawal data (Gassert et al. 2015) following the methodology presented by Gassert et al. (2013).

Results

- The water scarcity Estimated Costs stem from the need to close the global gap between renewable water supply and water demand, estimated here at 2,680 km^3 by 2030. With an expected total annual withdrawal of 4,670 km^3 in 2030 from domestic, industrial, and agricultural sources, the gap accounts for 56 percent of total 2030 withdrawals (Luck et al. 2015).
- The cost to close this gap is estimated at $445 billion annually, accounting for 43 percent of the global SDG 6 investment needs—by far the largest single driver of needed global SDG 6 investment.
- In terms of opportunity to save total water volume, the agricultural sector has the greatest expected savings at 73 percent of the anticipated global water gap. The domestic and industrial sectors, as well as water made available through large supply-side infrastructure solutions, account for the remaining 27 percent.
- The cost of water savings solutions varies greatly for each sector, with the most economically efficient gains in the agricultural sector and the least economically efficient gains in the industrial sector. Due to the variation in costs, the industrial sector accounts for the largest costs to close the water scarcity gap at 49 percent of the total needed investment, followed by the agricultural sector at 38 percent.

The percentage of water that each sector can save, under the projected conditions, is presented in Figure A6, and the Global Estimated Cost breakdowns are presented in Figure A7. Each sector can achieve water savings with different average costs; thus, although each sector must contribute to resolving water scarcity, the costs are not evenly distributed. Furthermore, each location, due to local socioeconomic and environmental conditions, will have different sectors facing the largest costs (Figure A8).

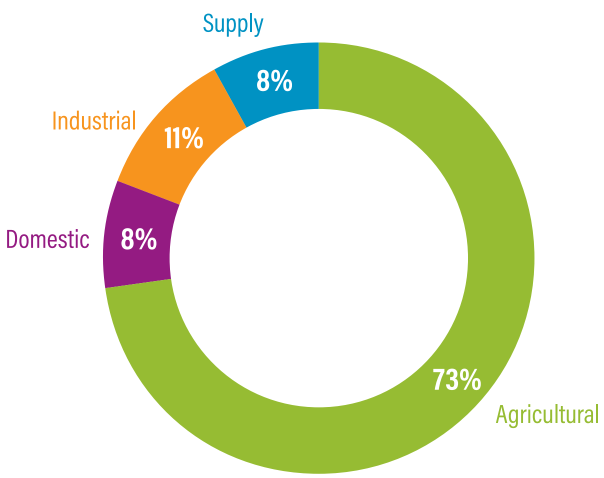
The industrial sector accounts for the bulk of the total Estimated Cost at $220 billion annually, even though industry only accounts for about 11 percent of the total possible water savings by 2030. The driving factor here is simply the cost of solutions, with a median cost of $1.04/$m^3$ and an interquartile range from $0.60–$1.90/m3. The upper bound of this range is higher than solutions for other sectors, resulting in the high overall cost to achieve global water savings for the industrial sector. The cheaper end of these water savings solutions includes standard industrial water efficiency measures, efficient washing equipment, water pressure reduction, and leakage reduction activities. However, the high average cost of industrial water savings is driven by the high-end solutions: water reuse and recycling, less-water intensive cooling technology, and zero discharge systems. The cost and feasibility of these solutions vary by type of industry; nonetheless, these more advanced solutions are far more expensive (per m^3) than other technologies and create a large range of costs for closing countries' industrial water gap.

The agricultural sector accounts for 38 percent of needed water scarcity investment at $167 billion annually. However, it is important to note that this investment yields 73 percent of needed global water savings. The surprisingly low cost of closing the agricultural water scarcity gap is driven by the low cost of delivering water savings to a country's agricultural sector. The median cost is $0.16/$m^3$ with an interquartile range of $0.10–$0.26/m^3. The cheapest water savings solutions actually result in both water savings and financial savings due to lower operations costs. These solutions include irrigation scheduling, improved fertilizer balance, drip irrigation, drainage construction, and no-till agriculture. The higher end of agricultural water solutions includes more advanced sprinkler systems, agricultural wastewater treatment and reclamation, using genetically modified crops, and large irrigation network improvements. However, even these more expensive solutions do not approach the cost of delivering water savings for other sectors. Consequently, investment in agricultural water savings is the best opportunity (and perhaps largest challenge) for resolving the water scarcity gap by 2030.

Domestic and supply-side solutions account for relatively low Estimated Costs ($46 billion and $12 billion, respectively) and yield a low percentage of the global water savings by 2030, about 8 percent of the global gap each (Figure A6). For domestic solutions, the median cost is $0.32/$m^3$, which falls above the median agricultural Solution Costs, but it is still far lower than median industrial costs. Given that the domestic sector only accounts for 8 percent of needed water savings, though, the final cost is smaller relative to other sectors. Lower-end domestic solutions include household or utility leakage reductions, pressure management, demand management schemes, and distribution network improvements. More expensive domestic solutions include domestic wastewater reuse, wastewater reclamation, and aquifer recharge with stormwater.

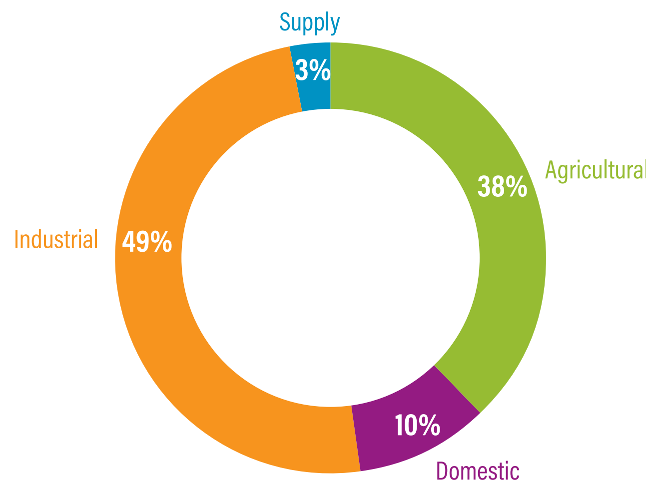
Supply-side solutions were derived from an average cost of major supply-side infrastructure projects, such as small and large dams, desalination plants, major basin transfers, and groundwater pumping. The median cost of supply-side water delivery is $0.07/$m^3$; however, this cost is annualized over longer time periods than sector-specific solutions. Whereas major capital spending for sector-specific solutions is annualized over 5-, 10-, or even 15-year periods depending on the project, these proposed supply-side solutions can be annualized at 30 or 50 years. This annualization period makes the cost of supply-side infrastructure appear artificially low. The $12 billion estimate does not include the cost of supply-side infrastructure delivering water beyond 2030, and the up-front investment requirement for supply-side solutions far exceeds the up-front cost for smaller, sector-specific solutions. Therefore, although these costs superficially seem to be an efficient way to close the 2030 water scarcity gap, this paper views major supply solutions as a last-effort cost to be integrated into a suite of sector efficiency solutions only when the water gap cannot be closed by other means.

Figure A6 | **Global Breakdown of Water Scarcity Gap**



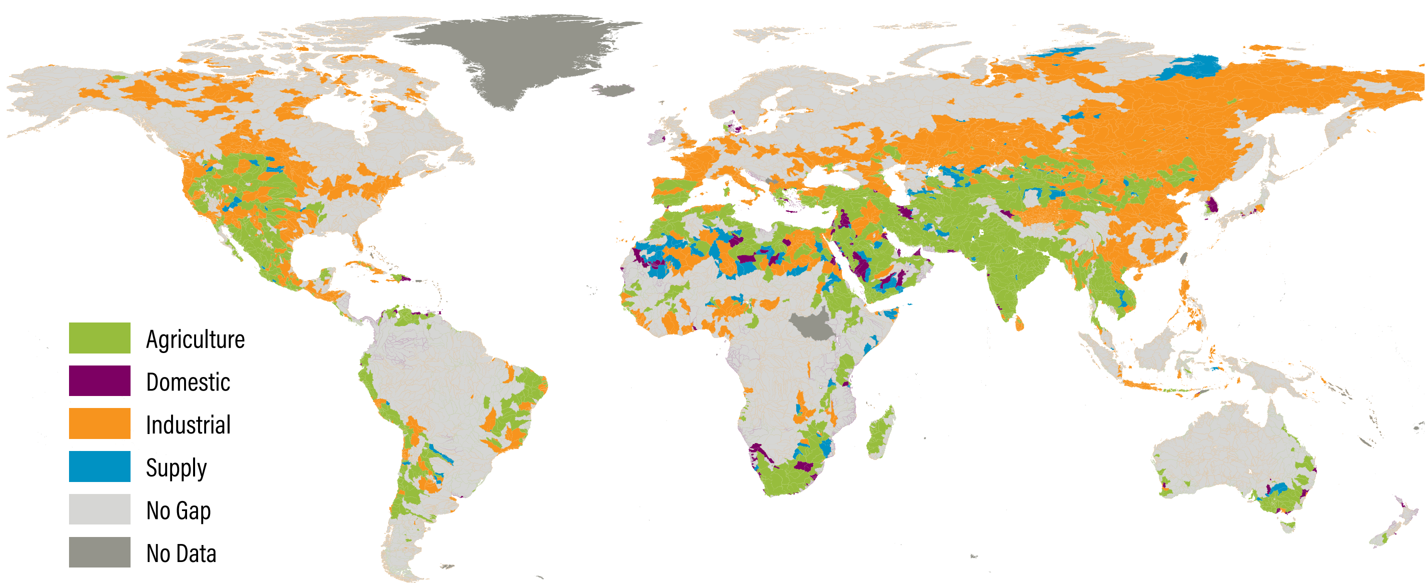
Note: Percentages indicate the volume of the global water scarcity gap each sector would deliver if optimal sector water efficiency were achieved. Optimal sector efficiency is determined by the top 20th percentile of sectors in terms of water use intensity.
Source: Authors.

Figure A7 | **Global Breakdown of Water Scarcity Estimated Costs**



Note: Water Scarcity Estimated Costs represent the cost of delivering each sectors' water savings (Figure A6).
Source: Authors.

Figure A8 | **Largest Cost to Close the Water Scarcity Gap per Catchment**



Note: Figure A8 shows which sector has the highest Estimated Cost within each catchment. The sector with the highest cost is not necessarily responsible for the largest water savings.
Source: Authors.

Other publications have attempted to estimate the cost to close the water scarcity gap by 2030:

- The 2030 WRG (2009) estimated an annual expenditure of $50–$60 billion by 2030 to close the water scarcity gap. This estimate was based on extrapolating national GDP expenditures on water scarcity infrastructure out to 2030 and is far lower than this study's estimated $445 billion annually.
- The difference between these numbers is partially driven by a large demand gap. This study estimates the gap between available water resources and projected water demand at 2,680 km^3, slightly lower than the estimate of 2,800 km^3 identified by the 2030 WRG (2009). However, the total projected demand for this study is 4,670 km^3, putting the needed water reduction at 56 percent of projected withdrawals (Gassert et al. 2015). This estimate is significantly higher than the previously estimated ratio of 40 percent future withdrawals (2030 WRG 2009).

Discussion

The Estimated Cost for water scarcity cannot be distinguished from the pathway used (i.e., set of solutions adopted) to eliminate water scarcity. A lower Estimated Cost than the estimates from this paper could be achieved if a country relied solely upon the most economically efficient water savings solutions. Likely this would mean a heavier reliance on agricultural, and potentially domestic, water savings solutions, as these are more economically efficient approaches to closing country water gaps. Rather than take the total least-cost approach, this paper selected a method of requiring all sectors to achieve an optimum sectoral target efficiency, and then the cost to achieve that efficiency was estimated. Although more expensive than the least-cost approach, the sectoral target approach may be more politically feasible in the long run. However, major limitations to this approach include the following:

Confidence Interval: SDG 6.4, Water Scarcity

	AGRICULTURAL	DOMESTIC	INDUSTRIAL	SUPPLY
Projected Gap	High	High	High	High
Solution Costs	Medium	Medium	Medium	Low
Estimated Costs	Medium	Medium	Medium	Medium

Source: Authors.

- For the agricultural and industrial sectors, each country's possible water savings were determined by the output of the sector. This assumption will distort the locations where water savings are possible—likely overestimating possible water savings in locations with low-value production (e.g., barley production) and underestimating possible water savings in locations with high-value production (e.g., citrus farming).
- To establish each country's possible water savings, an "optimal efficiency" standard was developed for agricultural, domestic, and industrial water use. Optimal efficiency was set as the 20th quantile of country efficiencies. This assumes that all countries above the 20th quantile in terms of sector efficiency can achieve the optimal efficiency, and it assumes that countries above the optimal efficiency need to make little to no improvements.
- For each country sector, the cost to deliver a water savings solution was estimated based on relevant water-efficiency solutions and the country's PPP. However, in applying the $\$/m^3$ estimates derived from these solutions, it is assumed that more efficiency sectors have already benefited from water-savings technology. In other words, this paper does not account for the specific feasibility of a given solution in a country; instead, it assumes that highly inefficient sectors have implemented little to no water efficiency measures and highly efficient sectors have already implemented the most cost-effective water efficiency measures. Assuming that water-efficient sectors only have access to the most expensive water-savings solutions will likely overestimate overall costs to eliminate water scarcity.

SDG 6.5: Integrated Water Resources Management

SDG 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

There are a variety of definitions of water management or water governance designed to serve different objectives. These are a few of the definitions:

- Integrated water resources management (IWRM) refers to "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP 2011).
- The World Bank defines water resource management as "the process of planning, developing, and managing water resources, in terms of both water quantity and quality, across all water uses. It includes the institutions, infrastructure, incentives, and information systems that support and guide water management" (World Bank, n.d.a).
- The OECD defines water governances as "the set of rules, practices, and processes (formal and informal) through which decisions for the management of water resources and services are taken and implemented, stakeholders articulate their interest and decision-makers are held accountable" (OECD 2015).

Although useful within their respective contexts, these definitions are too complex—given existing data—to translate into a viable Estimated Cost for the global results in this paper. Consequently, this paper has settled for an incomplete but directionally useful interpretation of water management: the oversight, planning, and legislative activities associated with national management of water utilities, regulatory authorities, and basin administration. This set of activities is insufficient as a complete assessment of water management, but these activities are useful because they can be tied to tangible costs.

The desired end state for water management is to ensure that national oversight, planning, and legislative activities align with additional investment in access to drinking water, sanitation services, water availability measures, and water pollution reduction measures. This outcome is not rooted in a Projected Gap and is designed to ensure that there is investment in water management to match the solutions developed for other water resource challenges.

Estimated Cost

To estimate the governance and management capacity gap, a target expenditure rate (as a percentage of total required investments) was applied to the aggregate of other Estimated Costs. Measuring the existence or lack of water management institutions can be difficult; thus, to identify an Estimated Cost for IWRM, a percentage modifier of 20 percent was developed based on case studies.

The literature suggests a range of costs for water management expenses: the UK reports spending between 1 and 4 percent of total investment (to meet the European Water Framework Directive) in the water sector to manage and oversee other investments, whereas France reports 6 percent of the expenditure in the water sector is spent on management and "general administration" (EU 2000; De Nocker et al. 2007; Stanley et al. 2012). The Netherlands spends 20 percent on administrative costs, including plan development, preparation, and also legislative expenses (De Nocker et al. 2007). The Dutch expenditure on water management is backed by decades of historical data. This information was instrumental in selecting the standard percentage modifier of 20 percent to be a very conservative estimate for achieving the management conditions necessary to deliver sustainable water management.

Results

The second-highest global Estimated Cost relates to the management systems required to cover the cost of all other water-related investments, totaling $173 billion per year. Unlike water scarcity or other Estimated Costs, water management estimates were not derived from a gap in water management capacity. Instead, they were based on case studies showing that roughly 20 percent of water-related spending in countries with advanced water management practices is devoted to managing existing or new expenditures; therefore, this Estimated Cost depends on other costs. Water management investments almost certainly vary based on context. However, there is currently a lack of management data, making localized management gaps difficult to estimate (Kölbel et al. 2018). The global management cost is an essential figure because current assessments of investments required to achieve all aspects of sustainable water management (e.g., eliminating eutrophication or the water scarcity gap) frequently ignore the additional management costs that exist beyond the mere implementation of specific solutions.

Confidence Interval: SDG 6.5, Water Management

Projected Gap	N/A
Solution Costs	Low
Estimated Cost	Low

Source: Authors.

Discussion

- Lack of data on water management makes a management gap difficult to calculate. However, selecting an alternative method to calculate water management Estimated Costs creates a nonstandard methodology across Estimated Costs. This also closely links the Estimated Cost to the magnitude of other Estimated Costs for a country or major river basin.

- Extrapolating data from the Netherlands generates a high bar for water management expenditure for locations that may not experience similar magnitudes of water-related hazards or may not operate in a highly economically developed context. Consequently, the water management Estimated Costs function as a conservative estimate of management costs relative to other investments put towards water challenges.

ENDNOTES

1. For example, Ozment et al. (2019) estimate a net benefit of $68.5 million (2019$) in São Paulo if 4,000 hectares were reforested to control sediment pollution.

2. For example, see Young and Loomis (2014); Morgan and Orr (2015); Natural Capital Coalition (2015); UNSD (2007); Park et al. (2015); Aylward et al. (2010); Ridley and Boland (2015); WBCSD (2013); and BIER (2015).

3. Capital expenditure is annualized over the expected life span of the project, which can range from 2 to 5 years for smaller projects to 45 years for major supply-side infrastructure projects.

4. This summary is not intended to prescribe priorities for the selected countries (which should determine policies and investments based on national data and political context) but rather to showcase a possible analysis and application of the Global Estimated Costs.

5. Following Hutton and Varughese (2016), safe management includes extraction through conveyance to safe treatment and disposal but excludes latrine costs (these are included in the basic sanitation costs).

6. Gachango et al. 2015; Hellsten et al. 2017; Jones et al. 2010; Lam et al. 2011; Webb et al. 2006; Liu et al. 2014; Oenema et al. 2009; Vibart et al. 2015.

REFERENCES

Abell, R., N. Asquith, G. Boccaletti, L. Bremer, E. Chapin, A. Erickson-Quiroz, J. Higgins, et al. 2017. *Beyond the Source: The Environmental, Economic and Community Benefits of Source Water Protection*. Arlington, VA: The Nature Conservancy. https://www.nature.org/content/dam/tnc/nature/en/documents/Beyond_The_Source_Full_Report_FinalV4.pdf.

AWS (Alliance for Water Stewardship). 2019. *International Water Stewardship Standard*: *Version 2.0.* North Berwick, Scotland: AWS.

Aylward, B., H. Seely, R. Hartwell, and J. Dengel. 2010. *The Economic Value of Water for Agricultural, Domestic and Industrial Uses: A Global Compilation of Economic Studies and Market Prices*. Bend, OR: Ecosystem Economics.

Beusen, A.H.W., A.F. Bouwman, L.P.H. Van Beek, J.M. Mogollón, and J.J. Middelburg. 2016. "Global Riverine N and P Transport to Ocean Increased during the Twentieth Century Despite Increased Retention along the Aquatic Continuum." *Biogeosciences* 13: 2441–51 https://doi.org/10.5194/bg-13-2441-2016.

Beusen, A.H.W., L.P.H. Van Beek, A.F. Bouwman, J.M. Mogollón, and J.J. Middelburg. 2015. "Coupling Global Models for Hydrology and Nutrient Loading to Simulate Nitrogen and Phosphorus Retention in Surface Water—Description of IMAGE—GNM and Analysis of Performance." *Geoscientific Model Development* 8: 4045–67. https://doi.org/10.5194/gmd-8-4045-2015.

BIER (Beverage Industry Environmental Roundtable). 2015. *BIER True Cost of Water Toolkit 2.0.* https://www.bieroundtable.com/publication/true-cost-of-water-toolkit/.

Bouwman, A.F., A.H.W. Beusen, J.A. Harrison, and D.C. Reed. 2015. *Nutrient Release in Global Coastal Marine Ecosystems, and Modeling of Impacts (Hypoxia, Harmful Algal Blooms and Fisheries) in Relation to Coastal Conditions*. B2/B3-1. Nairobi: United Nations Environment Programme. http://www.nutrientchallenge.org/sites/default/files/documents/files/Publications/B2-B3-1_Nutrient%20release%20and%20modeling%20impacts.pdf.

CDP. 2015. *Accelerating Action: CDP Global Water Report 2015.* London: CDP. https://www.cdp.net/en/research/global-reports/global-water-report-2015.

CDP. 2017. *A Turning Tide: Tracking Corporate Action on Water Security—CDP Global Water Report 2017.* London: CDP. https://www.cdp.net/en/research/global-reports/global-water-report-2017.

De Nocker, L., S. Broekx, I. Liekens, B. Gorlach, J. Jantzen, and P. Campling. 2007. *Costs and Benefits Associated with the Implementation of the Water Framework Directive, with a Special Focus on Agriculture*. Brussels: European Commission. https://ec.europa.eu/environment/water/water-framework/economics/pdf/framework_directive_economic_benefits.pdf.

Directorate-General for Environment. 2003. *Extensive Wastewater Treatment Processes Adapted to Small and Medium Sized Communities (500 to 5,000 Population Equivalents). Luxembourg: Publications Office of the European Union.*

EU (European Union). 2000. "Directive 2000/60/EC of the European Parliament and of the Council Establishing a Framework for Community Action in the Field of Water Policy." *Official Journal of the European Communities* L327 (22.12.2000). https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF.

FAO (Food and Agriculture Organization of the United Nations) GeoNetwork. 2015. "World Map of the Major Hydrological Basins (Derived from HydroSHEDS)." http://www.fao.org/geonetwork/srv/en/main.home?uuid=7707086d-af3c-41cc-8aa5-323d8609b2d1.

Gachango, F., S. Pedersen, and C. Kjaergaard. 2015. "Cost-Effectiveness Analysis of Surface Flow Constructed Wetlands (SFCW) for Nutrient Reduction in Drainage Discharge from Agricultural Fields in Denmark." *Environmental Management* 56 (6): 1478–86. http://doi.org/10.1007/s00267-015-0585-y.

Gassert, F., P. Reig, T. Luo, and A. Maddocks. 2013. "Aqueduct Country and River Basin Rankings: A Weighted Aggregation of Spatially Distinct Hydrological Indicators." Working Paper. Washington, DC: World Resources Institute. http://www.wri.org//publication/aqueduct-country-river-basin-rankings.

Gassert, F., P. Reig, T. Shiao, M. Luck, and M. Landis. 2015. "Aqueduct Global Maps 2.1 Indicators: Constructing Decision-Relevant Global Water Risk Indicators." Working Paper. Washington, DC: World Resources Institute. http://www.wri.org/publication/aqueduct-global-maps-21-indicators.

GWP (Global Water Partnership). 2011. "About IWRM." http://www.gwp.org/en/GWP-Caribbean/WE-ACT/About-IWRM/.

Hellsten, S., T. Dalgaard, K. Rankinen, K. Tørseth, A. Kulmala, E. Turtola, and F. Moldan, et al. 2017. *Nordic Nitrogen and Agriculture: Policy, Measures and Recommendations to Reduce Environmental Impact*. Copenhagen: Nordic Council of Ministers. https://doi.org/10.6027/TN2017-547.

Hernández-Sancho, F., M. Molinos-Senante, and R. Sala-Garrido. 2011. "Cost Modelling for Wastewater Treatment Processes." *Desalination* 268 (1–3): 1–5. https://doi.org/10.1016/j.desal.2010.09.042.

Hoekstra, A.Y., and M.M. Mekonnen. 2011. *Global Water Scarcity: Monthly Blue Water Footprint Compared to Blue Water Availability for the World's Major River Basins*. Value of Water Research Report Series 53. Delft, Netherlands: United Nations Educational, Scientific and Cultural Organization, Institute for Water Education.

Hofste, R., S. Kuzma, P. Reig, S. Walker, E.H. Sutanudjaja, M.F.P. Bierkens, M. Kuijpers-Linde, M. Faneca Sanchez, R. van Beek, S. Galvis Rodriguez, and Y. Wada. 2019. "Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators." Technical Note. Washington, DC: World Resources Institute.

Hutton, G. 2012. *Global Costs and Benefits of Drinking Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage*. Geneva: World Health Organization. https://www.who.int/water_sanitation_health/publications/2012/globalcosts.pdf.

Hutton, G., and M. Varughese. 2016. *The Costs of Meeting the 2030 Sustainable Development Goal Targets on Drinking Water, Sanitation and Hygiene.* Washington, DC: Water and Sanitation Program, World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/23681/K8632.pdf?sequence=4.

Jones, C., M. Selman, E. Branosky, and M. Perez. 2010. "How Nutrient Trading Could Help Restore the Chesapeake Bay." Working Paper. Washington, DC: World Resources Institute. http://www.wri.org/publication/how-nutrient-trading-could-help-restore-chesapeake-bay.

Kölbel, J., C. Strong, C. Noe, and P. Reig. 2018. *Mapping Public Water Management by Harmonizing and Sharing Corporate Water Risk Information.* Washington, DC: World Resources Institute. https://www.wri.org/publication/mapping-public-water.

Lam, Q.D., B. Schmalz, and N. Fohrer. 2011. "The Impact of Agricultural Best Management Practices on Water Quality in a North German Lowland Catchment." *Environmental Monitoring Assessment* 183 (1–4): 351–79. https://doi.org/10.1007/s10661-011-1926-9.

Liu, C., C. Kroeze, A.Y. Hoekstra, and W. Gerbens-Leenes. 2012. "Past and Future Trends in Grey Water Footprints of Anthropogenic Nitrogen and Phosphorus Inputs to Major World Rivers." *Ecological Indicators* 18 (July): 42–49. https://doi.org/10.1016/j.ecolind.2011.10.005.

Liu, R., P. Zhang, X. Wang, J. Wang, W. Yu, and Z. Shen. 2014. "Cost-Effectiveness and Cost-Benefit Analysis of BMPS in Controlling Agricultural Nonpoint Source Pollution in China Based on the SWAT Model." *Environmental Monitoring Assessment* 186 (12): 9011–22. https://doi.org/10.1007/s10661-014-4061-6.

Luck, M., M. Landis, and F. Gassert. 2015. "Aqueduct Water Stress Projections: Decadal Projections of Water Supply and Demand Using CMIP5 GCMs." Technical Note. Washington, DC: World Resources Institute. http://www.wri.org/publication/aqueduct-water-stress-projections-decadal-projections-water-supply-and-demand-using.

Mekonnen, M.M., and A.Y. Hoekstra. 2015. "Global Gray Water Footprint and Water Pollution Levels Related to Anthropogenic Nitrogen Loads to Fresh Water." *Environmental Science and Technology* 49 (21): 12860–68. https://doi.org/10.1021/acs.est.5b03191.

Mekonnen, M.M., and A.Y. Hoekstra. 2018. "Global Anthropogenic Phosphorus Loads to Fresh Water and Associated Grey Water Footprints and Water Pollution Levels: A High-Resolution Global Study." *Water Resources Research* 54 (1): 345–58. https://doi.org/10.1002/2017WR020448.

Morgan, A.J., and S. Orr. 2015. *The Value of Water: A Framework for Understanding Water Valuation, Risk and Stewardship*. Discussion Draft. Gland, Switzerland: World Wide Fund for Nature International; Washington, DC: International Finance Corporation. https://commdev.org/pdf/publications/The-Value-of-Water-Discussion-Draft-Final-August-2015.pdf.

Natural Capital Coalition. 2015. *The Natural Capital Protocol: Feedback Report from Business Engagement Partner Interviews*. London: Natural Capital Coalition. http://www.naturalcapitalcoalition.org/js/plugins/filemanager/files/Natural_Capital_Coalition_Business_Engagement_Partner_Interview_Report.pdf.

OECD (Organisation for Economic Co-operation and Development). 2006. *Infrastructure to 2030: Telecom, Land Transport, Water and Electricity.* Paris: OECD. https://doi.org/10.1787/9789264023994-en.

OECD. 2015. *OECD Principles on Water Governance.* Paris: OECD. http://www.oecd.org/governance/oecd-principles-on-water-governance.htm.

Oenema, O., H.P. Witzke, Z. Klimont, J.P. Lesschen, and G.L. Velthof. 2009. "Integrated Assessment of Promising Measures to Decrease Nitrogen Losses from Agriculture in EU-27." *Agriculture, Ecosystems & Environment* 133 (3–4): 280–88. https://doi.org/10.1016/j.agee.2009.04.025.

Otto, B., and L. Schleifer. 2018. "3 Things Cities Can Learn from Cape Town's Impending 'Day Zero' Water Shut-Off." *Insights* (blog), February 15. http://www.wri.org/blog/2018/02/3-things-cities-can-learn-cape-towns-impending-day-zero-water-shut.

Ozment, S., R. Feltran-Barbieri, P. Hamel, E. Gray, J. Ribeiro, S. Barrêto, A. Padavezi, and T.P. Valente. 2019. *Natural Infrastructure in São Paulo's Water System*. Washington, DC: World Resources Institute. https://www.wri.org/publication/natural-infrastructure-sao-paulo.

Palanichamy, R.B. 2019. "How Does a Flood-Prone City Run Out of Water? Inside Chennai's 'Day Zero' Crisis." *Insights* (blog), June 25. https://www.wri.org/blog/2019/06/how-does-flood-prone-city-run-out-water-inside-chennai-day-zero-crisis.

Park, A., S. Gauo, L. van Ast, I. Mulder, and A. Nordheim. 2015. *Water Risk Valuation Tool: Integrating Natural Capital Limits into Financial Analysis of Mining Stocks.* New York: Bloomberg. https://www.bbhub.io/sustainability/sites/6/2015/09/Bloomberg_WRVT_09162015_WEB.pdf.

Pastor, A.V., F. Ludwig, H. Biemans, H. Hoff, and P. Kabat. 2014. "Accounting for Environmental Flow Requirements in Global Water Assessments." *Hydrology and Earth System Sciences* 18 (12): 5041–49. https://doi.org/10.5194/hess-18-5041-2014.

Ramankutty, N., A.T. Evan, C. Monfreda, and J.A. Foley. 2008. "Farming the Planet: 1. Geographic Distribution of Global Agricultural Lands in the Year 2000." *Global Biogeochemical Cycles* 22: GB1003. https://doi.org/10.1029/2007GB002952.

Ridley, M., and D. Boland. 2015. *Integrating Water Stress into Corporate Bond Credit Analysis: Benchmarking Companies in Three Sectors.* Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit; Geneva: Natural Capital Declaration; and Frankfurt, Germany: Verein fuer Umweltmanagement und Nachhaltigkeit in Finanzinstituten. https://naturalcapital.finance/wp-content/uploads/2018/11/INTEGRATING-WATER-STRESS-REPORT_FINAL.pdf.

Sadoff, C.W., J.W. Hall, D. Grey, J.C.J.H. Aerts, M. Ait-Kadi, C. Brown, A. Cox, S. Dadson, D. Garrick, J. Kelma, P. McCornick, C. Ringler, M. Rosegrant, D. Whittington, and D. Wiberg. 2015. *Securing Water, Sustaining Growth: Report of the GWP/OECD Task Force on Water Security and Sustainable Growth*. Oxford: University of Oxford. https://www.water.ox.ac.uk/wp-content/uploads/2015/04/SCHOOL-OF-GEOGRAPHY-SECURING-WATER-SUSTAINING-GROWTH-DOWNLOADABLE.pdf.

Stanley, K., G. Depaoli, and P. Strosser. 2012. *Financing Water Management and the Economic Crisis—a Review of Available Evidence*. Colmar, France: ACTeon. https://ec.europa.eu/environment/archives/water/implrep2007/pdf/EU%20pressures%20and%20measures_Task_4b_Financing%20and%20the%20economic%20crisis_final%20version.pdf.

2030 WRG (Water Resources Group). 2009. *Charting Our Water Future: Economic Framework to Inform Decision-Making.* https://www.mckinsey.com/business-functions/sustainability/our-insights/charting-our-water-future.

2030 WRG. 2012. *A Catalogue of Good Practices in Water Use Efficiency: A Pilot Phase Report*. Stockholm: Stockholm International Water Institute. https://www.2030wrg.org/global-catalogue-of-good-practices/.

United Nations. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

UNSD (United Nations Statistics Division). 2007. *System of Environmental-Economic Accounting for Water.* New York: UNSD.

Van Huijstee, J., B. van Bemmel, A. Bouwman, and F. van Rijn. 2018. *Towards an Urban Preview: Modelling Future Urban Growth with 2UP.* Background Report 3255. The Hague, Netherlands: PBL Netherlands Environmental Assessment Agency. https://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2018-Towards-an-urban-preview_3255.pdf.

Van Vuuren, D.P., P.L. Lucas, and H. Hilderink. 2007. "Downscaling Drivers of Global Environmental Change: Enabling Use of Global SRES Scenarios at the National and Grid Levels." *Global Environmental Change* 17 (1): 114–30. https://doi.org/10.1016/j.gloenvcha.2006.04.004.

Vibart, R., I. Vogeler, S. Dennis, W. Kaye-Blake, R. Monaghan, V. Burggraaf, J. Beautrais, and A. Mackay. 2015. "A Regional Assessment of the Cost and Effectiveness of Mitigation Measures for Reducing Nutrient Losses to Water and Greenhouse Gas Emissions to Air from Pastoral Farms." *Journal of Environmental Management* 156 (1): 276–89. https://doi.org/10.1016/j.jenvman.2015.03.041.

Vörösmarty, C.J., B.M. Fekete, M. Meybeck, and R.B. Lammers. 2000. "Global System of Rivers: Its Role in Organizing Continental Land Mass and Defining Land-to-Ocean Linkages." *Global Biogeochemical Cycles* 14 (2): 599–621. https://doi.org/10.1029/1999GB900092.

WBCSD (World Business Council for Sustainable Development). 2013. *Business Guide to Water Valuation: An Introduction to Concepts and Techniques*. Geneva: WBCSD. https://www.wbcsd.org/4rTio.

Webb, J., M. Ryan, S.G. Anthony, A. Brewer, J. Laws, M.F. Aller, and T.H. Misselbrook. 2006. "Cost-Effective Means of Reducing Ammonia Emissions from UK Agricultural Using the NARSES Model." *Atmospheric Environment* 40 (37): 7222–33. https://doi.org/10.1016/j.atmosenv.2006.06.029.

WEF (World Economic Forum). 2019. *The Global Risks Report 2019.* 14th ed. Geneva: World Economic Forum. http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf.

WHO (World Health Organization) and UNICEF (United Nations Children's Fund). 2017. *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines.* Geneva: WHO; New York: UNICEF. https://www.unicef.org/publications/files/Progress_on_Drinking_Water_Sanitation_and_Hygiene_2017.pdf.

Winpenny, J. 2015. *Water: Fit to Finance? Catalyzing National Growth through Investment in Water Security*. Marseille, France: World Water Council. http://www.worldwatercouncil.org/sites/default/files/Thematics/WWC_OECD_Water_fit_to_finance_Report.pdf.

World Bank. 2016. *High and Dry: Climate, Water, and the Economy.* Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/862571468196731247/High-and-dry-climate-change-water-and-the-economy.

World Bank. 2018. *World Bank Open Data*. https://data.worldbank.org. Accessed July 2019.

World Bank. n.d.a. *Water Resources Management*. https://www.worldbank.org/en/topic/waterresourcesmanagement#2. Accessed September 2019.

World Bank. n.d.b. "World Bank Country and Lending Groups." https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed August 2019.

WRI (World Resources Institute). 2015. "Country Shapefiles and Boundaries for WRI." Unpublished document. https://github.com/wri/wri-bounds.

Xie, H., C. Ringler, and G. Pitois. 2016. "Assessing Global BOD, Nitrogen and Phosphorus Loadings under Socioeconomic and Climate Change Scenarios." Technical Note. Washington, DC: International Food Policy Research Institute.

Young, R.A., and J.B. Loomis. 2014. *Determining the Economic Value of Water: Concepts and Methods.* New York: Routledge. https://doi.org/10.4324/9780203784112.

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

ABOUT VALUING NATURE

The mission of Valuing Nature is to support organizations to integrate the value of nature into decision-making by providing innovative methodologies, data, and expertise. Valuing Nature, represented by Samuel Vionnet, was created in 2015. Vionnet is an independent consultant with 10 years of experience in sustainability and water stewardship, having worked for 6 years on water footprint, water valuation methods, and water-related databases while at Quantis International. He worked mostly with the private sector, supporting tens of different multinational companies mostly in Europe, North America, and South America. His work covers sustainability metrics; water stewardship; supply chain management/risk assessment; sustainability strategy; and natural, human, and social capital accounting. He now focuses Valuing Nature's activities on the socioeconomic dimensions of water, using the concepts of ecosystem services and natural and social capital accounting.

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