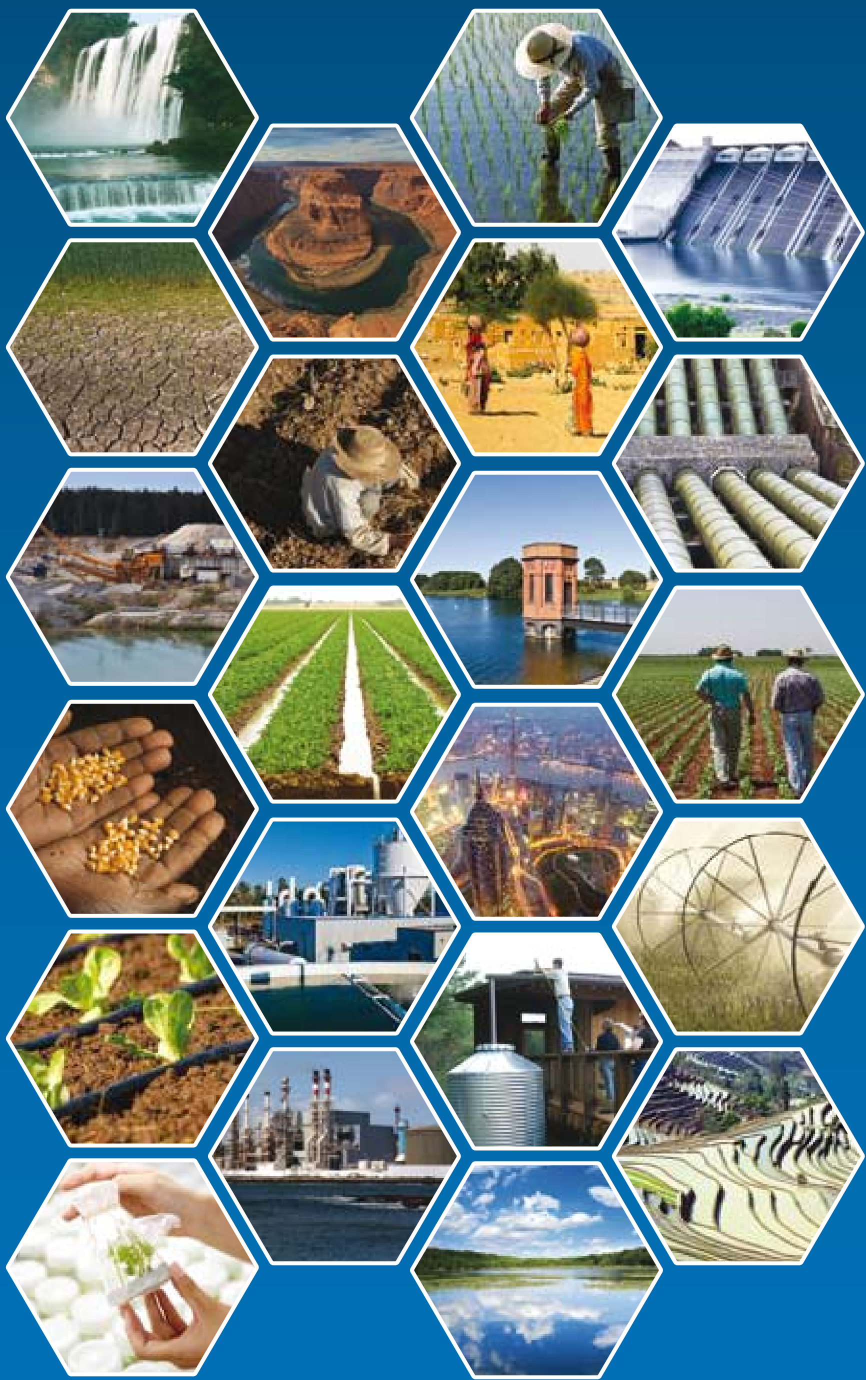
2030 WATER RESOURCES GROUP



Charting Our Water Future

Economic frameworks to inform decision-making

This report was prepared with the support and active participation of each member of the 2030 Water Resources Group, but the views expressed in it are not a reflection of any official policy of those sponsor organizations.

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The 2030 Water Resources Group

The 2030 Water Resources Group was formed in 2008 to contribute new insights to the increasingly critical issue of water resource scarcity. The group aimed to create an integrated fact base on the potential technical levers and costs for reducing water scarcity, with the ultimate goal of advancing solutions-driven dialogue among stakeholders.

The Group consists of a range of organizations from the private and social sectors, which provided the institutional collaboration and counsel needed to tackle this complex topic:

- Initiating sponsorship for the project came from **The International Finance Corporation (IFC),** part of the World Bank Group, which provides investments and advisory services to build the private sector in developing countries. The World Bank also provided substantial input from its experience in the water sector.

- **McKinsey & Company,** a global management consulting firm, provided overall project management, drove the analytical execution and developed the fact base for the report.

- An extended business consortium provided sponsorship, guidance, and expertise. This included: **The Barilla Group,** a global food group; **The Coca-Cola Company,** a global beverage company; **Nestlé S.A.,** a global nutrition, health, and wellness company; **SABMiller plc,** a global brewer; **New Holland Agriculture,** a global agricultural equipment company; **Standard Chartered Bank,** a global financial institution, and **Syngenta AG,** a global agribusiness.

Expert Advisory Group

In addition to the core sponsors, an expert advisory group provided invaluable advice on the methodology and content of this study. The advisory group was composed of:

- **Jamal Saghir,** Director, Energy, Water and Transport, **Abel Mejia,** Water Anchor Lead, and **Michael Jacobsen,** Senior Water Resources Specialist, World Bank Group
- **Anders Berntell,** Director General, and **Jakob Granit,** Program Director, Stockholm International Water Institute (SIWI)
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- **Peter Gleick,** President and **Jason Morrison,** Water Program Leader, Pacific Institute

We thank these advisors for their considerable input, yet the authors alone take full responsibility for the content and conclusions of this report.

The 2030 Water Resources Group also relied on the additional input from more than 300 experts and practitioners of leading scientific, multinational and nonprofit institutions who offered invaluable insights on methodology and detailed input into the regional case studies.

Above all, the active participation of government water resource managers in the various regional studies (Brazil, China, India, and South Africa) brought important thought partnership to the project and helped tailor our contribution to have the most utility to the public sector

A full list of these contributors can be found in the Acknowledgements section.

Foreword

His Royal Highness the Prince of Orange, Chairman of the United Nations Secretary-General's Advisory Board on Water and Sanitation

When I chaired the Second World Water Forum in The Hague in 2000, I set out a simple mission: to make water everyone's business. I am therefore gratified that the 2030 Water Resources Group—a consortium of mostly private companies from several important sectors of the world economy—has made it their business to put together this report. And indeed, the report's central message is that any strategy to achieve water resource security must be a joint effort—integrated with broader economic decision-making—by governments, investors, NGOs, and water users in agriculture, industry and cities.

The picture shown by the report is certainly sobering: The ever-expanding water demand of the world's growing population and economy, combined with the impacts of climate change, are already making water scarcity a reality in many parts of the world—and with it we are witnessing severe damage to livelihoods, human health, and ecosystems. In just 20 years, this report shows, demand for water will be 40 percent higher than it is today, and more than 50 percent higher in the most rapidly developing countries. Historic rates of supply expansion and efficiency improvement will close only a fraction of this gap. Unless local, national and global communities come together and dramatically improve the way we envision and manage water, there will be many more hungry villages and degraded environments—and economic development itself will be put at risk in many countries.

Encouragingly, though, the report also finds that the future "water gap" can be closed. Even in rapidly developing, water-scarce countries, there is a set of measures—to boost efficiency, augment supply, or lessen the water-intensity of the economy—that in principle could meet human and environmental water needs at affordable cost. The report shows how "crop per drop" can be increased dramatically in agriculture, which today consumes 70 percent of the world's water. This has also been the message the United Nations Secretary-General's Advisory Board on Water and Sanitation has kept on conveying to decision-makers: that water requires more political attention and strategic thinking.

What this report provides, however, is a toolkit that stakeholders can use to compare the impact, cost and achievability of a range of different measures and technologies, so providing the fact base needed to underpin solutions.

If water is to be everyone's business, then stakeholders will need to come together in water-scarce countries to make some difficult trade-offs on the road to water resource security. Some solutions may require potentially unpopular policy changes and the adoption of water-saving techniques and technologies by millions of farmers. The conversation needed amongst stakeholders, then, is about a country's economic and social priorities, what water will be needed to meet those priorities, and which difficult challenges are worth tackling to deliver or free up that water. This report's contribution is to create a common economic language which all stakeholders can use in participating in that conversation.

Of course, this report will have failed if it sparks no more than conversation. The fact base, frameworks and insights presented here must galvanize action. I therefore urge stakeholders in every country to apply the tools in this report to their own water challenges, bringing policymakers together with the private and social sectors to identify and implement solutions to use our most precious resource much more wisely and effectively.

HRH The Prince of Orange Willem-Alexander
Chairman of the United Nations Secretary-General's
Advisory Board on Water and Sanitation

Preface

The world is increasingly turning its attention to the issue of water scarcity. Many countries face water scarcity as a fundamental challenge to their economic and social development; by 2030 over a third of the world population will be living in river basins that will have to cope with significant water stress, including many of the countries and regions that drive global economic growth.

Across the globe, policy makers, civil society and the business sector are increasingly becoming aware of the challenge facing global water resources, and the need to carefully manage these resources. Progress has been limited, however, and overall too slow. One missing piece has been the lack of a rigorous analytical framework to facilitate decision-making and investment into the sector, particularly on measures of efficiency and water productivity.

The report *Charting Our Water Future* was developed to take a first step in providing greater clarity on the scale, costs and tradeoffs of solutions to water scarcity. It is the result of a year-long collaboration involving IFC (a member of the World Bank Group), McKinsey & Company, The Coca-Cola Company, Barilla, New Holland Agriculture, Nestlé, SABMiller plc, Standard Chartered Bank and Syngenta AG, and has relied on the input of over 300 specialists and public sector practitioners as well as the consistent guidance of a group of expert advisors.

We hope this is a useful contribution that can advance solutions and elevate the debate for what is an issue of critical importance to all.

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Shining a light on water resource economics

Constraints on a valuable resource should draw new investment and prompt policies to increase productivity of demand and augment supply. However, for water, arguably one of the most constrained and valuable resources we have, this does not seem to be happening. Calls for action multiply and yet an abundance of evidence shows that the situation is getting worse. There is little indication that, left to its own devices, the water sector will come to a sustainable, cost-effective solution to meet the growing water requirements implied by economic and population growth.

This study focuses on how, by 2030, competing demands for scarce water resources can be met and sustained. It is sponsored, written, and supported by a group of private sector companies and institutions who are concerned about water scarcity as an increasing business risk, a major economic threat that cannot be ignored, and a global priority that affects human well-being.

Assuring sufficient raw or "upstream" water resources is a precondition for solving other water issues, such as those of clean water supply in municipal and rural systems, wastewater services, and sanitation—the "downstream" water services. Yet the institutions and practices common in the water sector have often failed to achieve such security. A lack of transparency on the economics of water resources makes it difficult to answer a series of fundamental questions: What will the total demand for water be in the coming decades? How much supply will there still be? What technical options for supply and water productivity exist to close the "water gap"? What resources are needed to implement them? Do users have the right incentives to change their behaviors and invest in water saving? What part of the investment backlog must be closed by private sector efforts, and what part does the public sector play in ensuring that water scarcity does not derail either economic or environmental health?

In the world of water resources, economic data is insufficient, management is often opaque, and stakeholders are insufficiently linked. As a result, many countries struggle to shape implementable, fact-based water policies, and water resources face inefficient allocation and poor investment patterns because investors lack a consistent basis for economically rational decision-making. Even in countries with the most advanced water policies there is still some way to go before the water sector is managed with the degree of sophistication appropriate for our most essential resource. Without a step change improvement in water resource management, it will be very difficult to meet related resource challenges, such as providing sufficient food or sustainably generating energy for the world's population.

After careful quantitative analysis of the problem, this report provides some answers on the path to water resource security. It first quantifies the situation and shows that in many regions, current supply will be inadequate to meet the water requirements. However, as a central thesis, it also shows that meeting all competing demands for water is in fact *possible at reasonable* *cost*. This outcome will not emerge naturally from existing market dynamics, but will require a concerted effort by all stakeholders, the willingness to adopt a total resource view where water is seen as a key, cross-sectoral input for development and growth, a mix of technical approaches, and the courage to undertake and fund water sector reforms.

An upfront caveat is warranted. This work delivers—the authors believe—a mosaic of the solution by providing a comparative fact base on the economics of technical measures. We would thus portray it as a starting point, not a comprehensive solution to all water problems. We fully recognize that water is a multi-faceted good differentiated by type of use, quality, and delivery reliability, and thus a complex sociopolitical issue. And, we acknowledge the vast body of economic and political economy literature that has elaborated on such topics. This report does not intend to substitute for that work.

To those familiar with the water challenge, our endeavor might appear daunting, as the quality of the data is highly variable and often uncertain. We fully acknowledge these uncertainties and welcome contributions that can improve this study's accuracy and usefulness through better data. Yet we are convinced that rigorous analysis built off existing data can provide a sufficiently robust fact base for meaningful stakeholder dialogue and action towards solutions.

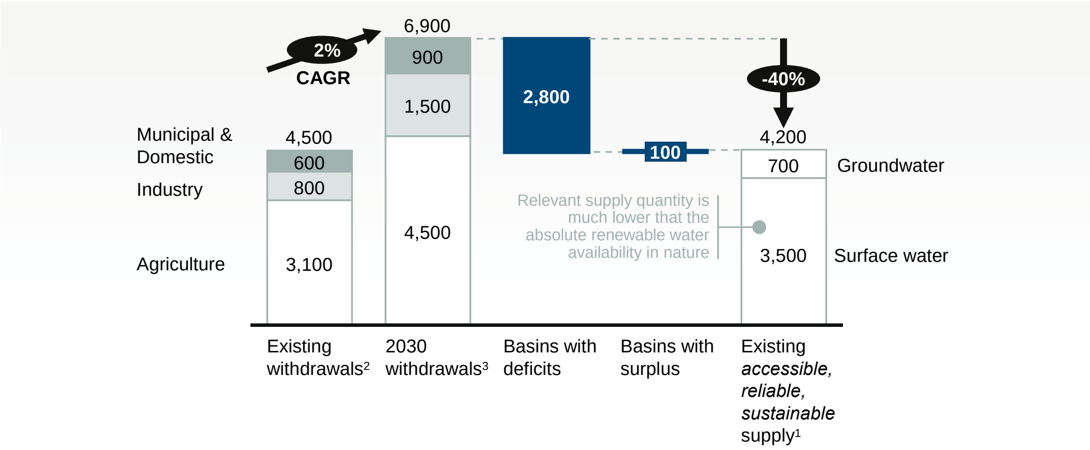
2 Managing our way to scarcity: The challenge ahead

By 2030, under an average economic growth scenario and if no efficiency gains are assumed, global water requirements would grow from 4,500 billion m^3 today (or 4.5 thousand cubic kilometers) to 6,900 billion m^3. As Exhibit 1 shows, this is a full 40 percent above current accessible, reliable supply (including return flows, and taking into account that a portion of supply should be reserved for environmental requirements). This global figure is really the aggregation of a very large number of local gaps, some of which show an even worse situation: one-third of the population, concentrated in developing countries, will live in basins where this deficit is larger than 50 percent. The quantity represented as accessible, reliable, environmentally sustainable supply—a much smaller quantity than the absolute raw water available in nature—is the amount that truly matters in sizing the water challenge.

Exhibit I

Aggregated global gap between existing accessible, reliable supply[1] and 2030 water withdrawals, assuming no efficiency gains

Billion m³, 154 basins/regions



1 Existing supply which can be provided at 90% reliability, based on historical hydrology and infrastructure investments scheduled through 2010; net of environmental requirements
2 Based on 2010 agricultural production analyses from IFPRI
3 Based on GDP, population projections and agricultural production projections from IFPRI; considers no water productivity gains between 2005-2030

SOURCE: Water 2030 Global Water Supply and Demand model; agricultural production based on IFPRI IMPACT-WATER base case

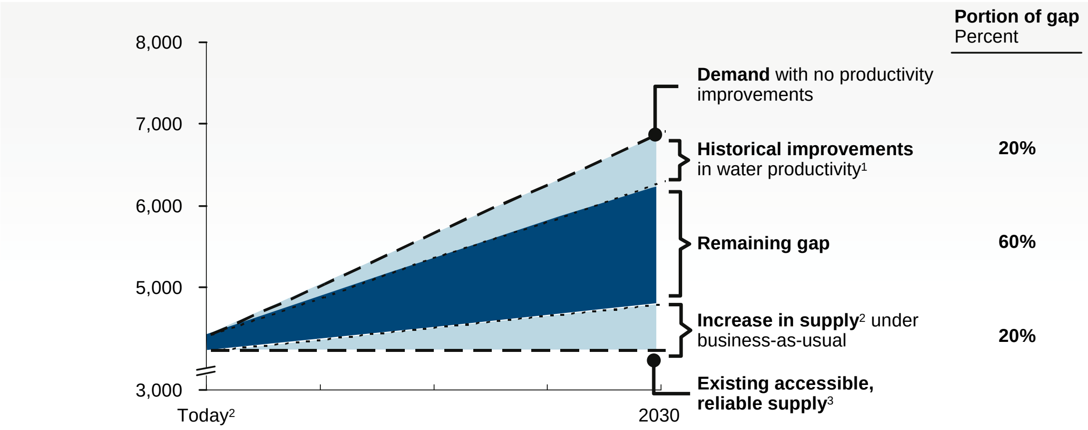
The drivers of this resource challenge are fundamentally tied to economic growth and development. Agriculture accounts for approximately 3,100 billion m³, or 71 percent of global water withdrawals today, and without efficiency gains will increase to 4,500 billion m³ by 2030 (a slight decline to 65 percent of global water withdrawals). The water challenge is therefore closely tied to food provision and trade. Centers of agricultural demand, also where some of the poorest subsistence farmers live, are primarily in India (projected withdrawals of 1,195 billion m³ in 2030), Sub-Saharan Africa (820 billion m³), and China (420 billion m³). Industrial withdrawals account for 16 percent of today's global demand, growing to a projected 22 percent in 2030. The growth will come primarily from China (where industrial water demand in 2030 is projected at 265 billion m³, driven mainly by power generation), which alone accounts for 40 percent of the additional industrial demand worldwide. Demand for water for domestic use will decrease as a percentage of total, from 14 percent today to 12 percent in 2030, although it will grow in specific basins, especially in emerging markets.

While the gap between supply and demand *will* be closed, the question is *how*. Given the patterns of improvement of the past, will the water sector land on an efficient solution that is environmentally sustainable and economically viable? There is every reason to believe it will not. The annual rate of efficiency improvement in agricultural water use between 1990 and 2004 was approximately 1 percent across both rain-fed and irrigated areas. A similar rate of improvement occurred in industry. Were agriculture and industry to sustain this rate to 2030, improvements in water efficiency would address only 20 percent of the supply-demand gap, leaving a large deficit to be filled. Similarly, a business-as-usual supply build-out, assuming constraints in infrastructure rather than in the raw resource, will address only a further 20 percent of the gap (Exhibit II). Even today, a gap between water demand and supply exists—when some amount of supply that is currently unsustainably "borrowed" (from nonreplenishable aquifers or from environmental requirements of rivers and wetlands) is excluded, or when supply is considered from the perspective of *reliable* rather than *average* availability.

Exhibit II

Business-as-usual approaches will not meet demand for raw water

Billion m3



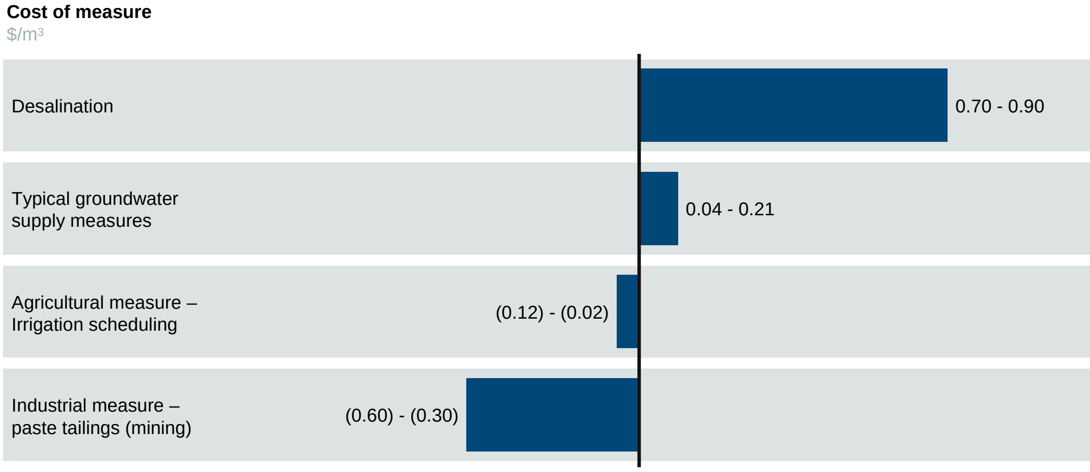
1 Based on historical agricultural yield growth rates from 1990-2004 from FAOSTAT, agricultural and industrial efficiency improvements from IFPRI
2 Total increased capture of raw water through infrastructure buildout, excluding unsustainable extraction
3 Supply shown at 90% reliability and includes infrastructure investments scheduled and funded through 2010. Current 90%-reliable supply does not meet average demand
SOURCE: 2030 Water Resources Group – Global Water Supply and Demand model; IFPRI; FAOSTAT

If these "business-as-usual" trends are insufficient to close the water gap, the result in many cases could be that fossil reserves are depleted, water reserved for environmental needs is drained, or—more simply—some of the demand will go unmet, so that the associated economic or social benefits will simply not occur. The impacts of global climate change on local water availability, although largely outside the scope of this study, could exacerbate the problem in many countries. While such impacts are still uncertain at the level of an individual river basin for the relatively short time horizon of 2030, the uncertainty itself places more urgency on addressing the status quo challenge.

The financial implications of this challenge are also clear. Historically, the focus for most countries in addressing the water challenge has been to consider additional supply, in many cases through energy-intensive measures such as desalination. However, in many cases desalination—even with expected efficiency improvements—is vastly more expensive than traditional surface water supply infrastructure, which in turn is often much more expensive than efficiency measures, such as irrigation scheduling in agriculture. These efficiency measures can result in a net increase in water availability, and even net cost savings when operating savings of the measures outweigh annualized capital costs (Exhibit III).

Exhibit III

Representative demand- and supply-side measures



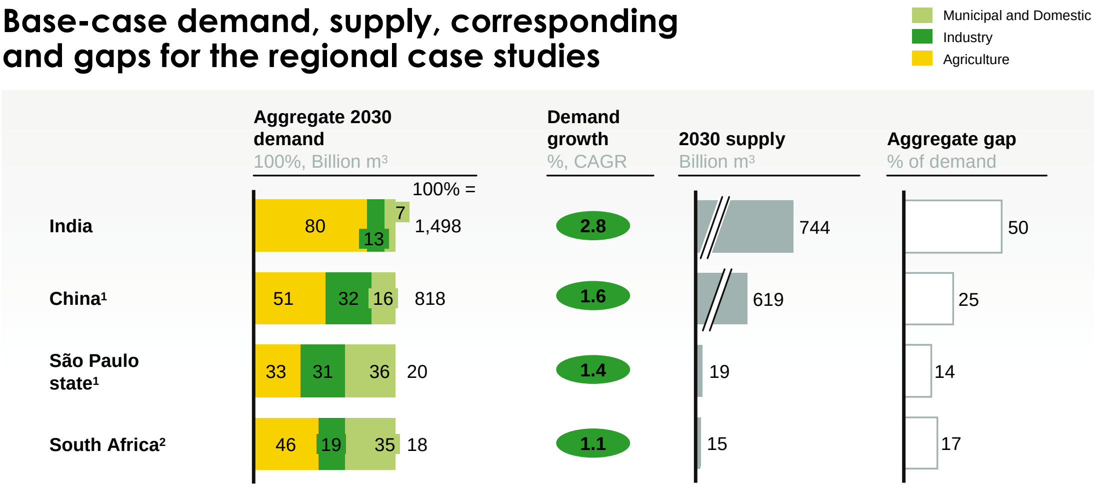
SOURCE: 2030 Water Resources Group

Closing the remaining gap through traditional supply measures would be costly: these face a steep marginal cost curve in many parts of the world, with many of the supply measures required to close the 2030 gap bearing a cost of more than $0.10/m³, against current costs in most cases, of under $0.10 /m³. The most expensive supply measures reach a cost of $0.50/m³ or more. Without a new, balanced approach, these figures imply additional annual investment in upstream water infrastructure of up to $200 billion over and above current levels—more than four times current expenditure.

This picture is complicated by the fact that there is no single water crisis. Different countries, even in the same region, face very different problems, and generalizations are of little help. We therefore conducted detailed case studies on three countries and one region challenged by dramatically different water issues: China; India; South Africa; and, the state of São Paulo in Brazil. (Exhibit IV).

Exhibit IV

Base-case demand, supply, corresponding and gaps for the regional case studies



1 Gap greater than demand-supply difference due to mismatch between supply and demand at basin level
2 South Africa agricultural demand includes a 3% contribution from afforestation
SOURCE: 2030 Water Resources Group

These case studies reflect a significant fraction of the global water challenge. In 2030, these countries collectively will account for 30 percent of world GDP and 42 percent of projected global water demand. They also address some of the main themes of the global water challenge, including:

- Competition for scarce water from multiple uses within a river basin
- The role of agriculture for food, feed, fiber and bioenergy as a key demand driver for water
- The nexus between water and energy
- The role of urbanization in water resource management
- Sustainable growth in arid and semi-arid regions

In each case study, we went to the highest level of granularity afforded by the accessible data, conducting analysis at the river basin or watershed level, and in many cases at the sub-basin level, as appropriate for each study. In each we created a "base case" scenario for water demand and supply in 2030 by projecting the country's water demand to 2030; calculating the expected gap between this 2030 demand figure and currently planned supply; and analyzing the underlying drivers of that gap.

For the countries studied, these 2030 base cases illustrate the powerful impact of macro-economic trends on the water sector.

By 2030, demand in **India** will grow to almost 1.5 trillion m^3, driven by domestic demand for rice, wheat, and sugar for a growing population, a large proportion of which is moving toward a middle-class diet. Against this demand, India's current water supply is approximately 740 billion m^3. As a result, most of India's river basins could face severe deficit by 2030 unless concerted action is taken, with some of the most populous—including the Ganga, the Krishna, and the Indian portion of the Indus—facing the biggest absolute gap.

China's demand in 2030 is expected to reach 818 billion m^3, of which just over 50 percent is from agriculture (of which almost half is for rice), 32 percent is industrial demand driven by thermal power generation, and the remaining is domestic. Current supply amounts to just over 618 billion m^3. Significant industrial and domestic wastewater pollution makes the "quality-adjusted" supply-demand gap even larger than the quantity-only gap: 21 percent of available surface water resources nationally are unfit even for agriculture. Thermal power generation is by far the largest industrial water user, despite the high penetration of water-efficient technology, and is facing increasing limitations in the rapidly urbanizing basins.

São Paulo state's projected demand in 2030 of 20.2 billion m^3 is evenly split between domestic, industrial, and agricultural requirements, against a current accessible, reliable supply of 18.7 billion m^3. Nearly 80 percent of this demand is reflected in the São Paulo macro-metropolitan region, with a projected population of 35 million in 2030. This quantity challenge is compounded by severe quality issues, as even today, low coverage of sanitation collection and treatment means that a significant proportion of São Paulo's water supply is polluted—requiring over 50 percent of current supply to the region to be transferred from neighboring basins.

Demand in **South Africa** is projected at 17.7 billion m^3 in 2030 with household demand accounting for 34 percent of the total. Against this, current supply in South Africa amounts to 15 billion m^3, and it is severely constrained by low rainfall, limited underground aquifers, and reliance on significant water transfers from neighboring countries. South Africa will have to resolve tough trade-offs between agriculture, key industrial activities such as mining and power generation, and large and growing urban centers.

In addition, we supplemented the detailed case studies with insights from other geographies to understand particular challenges (e.g. efficient water use in the arid countries of the Gulf Cooperation Council).

These regional water resources challenges have been characterized, as a base case, by the water resource availability and demand of *historical* climate conditions. Yet, all regions are faced by increased uncertainty in water resource availability as a result of the impact of global climate change. Without taking explicit scientific positions on how climate change will affect any one river basin, we do explore the major implications of climate change projections in some areas—for example, an "average" expectation of climate change for South Africa by 2030 shows a slight decrease in supply and a (more pronounced) increase in crop demand, growing the 2030 supply-demand gap by 30%.

3

Toward solutions: An integrated economic approach to water resource management

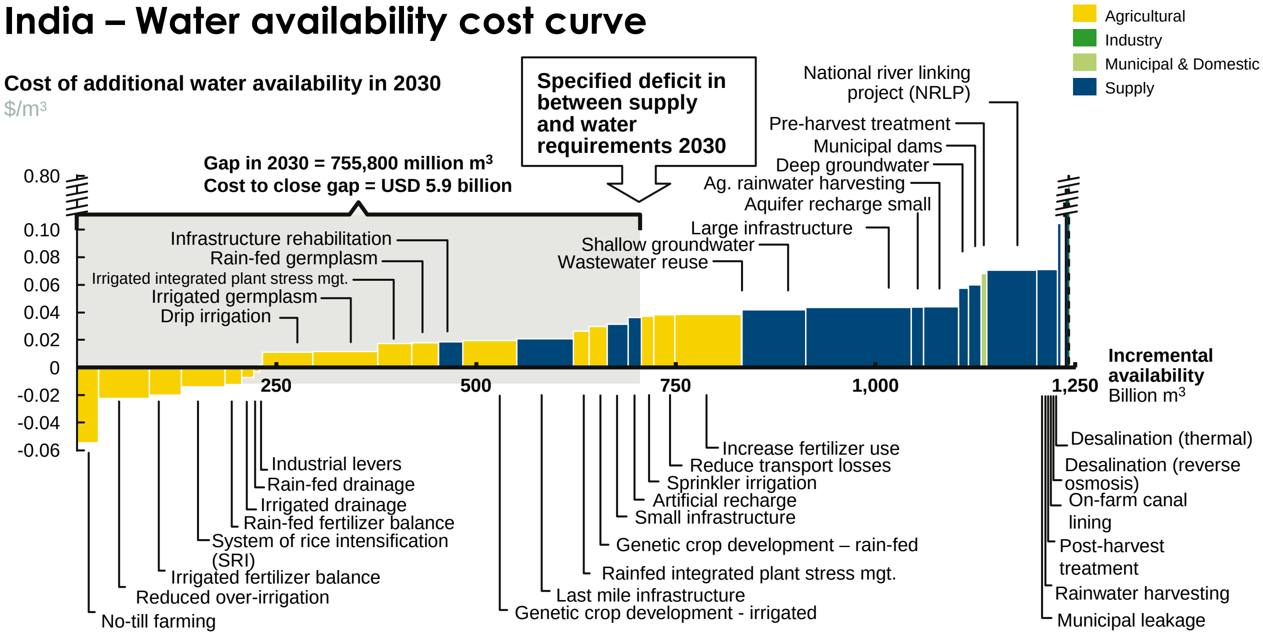
Solutions to these challenges are in principle possible and need not be prohibitively expensive. A solution in a particular basin or country would utilize a combination of three fundamental ways to close the demand-supply gap. Two of these are *ceteris paribus* options and focus on technical improvements, increasing supply and improving water productivity under a constant set of economic activities, while the third is tied to the underlying economic choices a country faces and involves actively reducing withdrawals by changing the set of underlying economic activities. A well-managed sector would identify a sustainable and cost-effective mix of these three solutions.

In our case studies we focused first on the two technical solutions, and in all cases identified cost-effective solutions to close the gaps calculated in the base cases. Across the four regions under study, these solutions would require $19 billion per annum in incremental capital investment by 2030—just 0.06 percent of their combined forecast GDP for 2030. When scaled to total global water demand, this implies an annual capital requirement of approximately $50 to $60 billion to close the water resource availability gap, if done in the least costly way available, almost 75% less than a supply-only solution.

The challenge in linking these opportunities to close the water gap lies in finding a way of comparing the different options. As a key tool to support decision-making, this study developed a "water-marginal cost curve", which provides a microeconomic analysis of the cost and potential of a range of existing technical measures to close the projected gap between demand and supply in a basin (Exhibit V provides an example of the cost curve for India). For a given level of withdrawals, the cost curve lays out the technical options to maintain water-dependent economic activities and close the gap, comparing on a like-for-like basis, efficiency and productivity measures with additional supply. Each of these technical measures is represented as a block on the curve. The width of the block represents the amount of additional water that becomes available from adoption of the measure. The height of the block represents its unit cost.

Exhibit V

India – Water availability cost curve



SOURCE: 2030 Water Resources Group

For each of the case studies, a basin-by-basin analysis of technical measures was conducted for the base case demand scenario. Then, departures from the base case in the form of alternative supply/demand scenarios were explored. The key findings for these cases are as follows.

Agricultural productivity is a fundamental part of the solution. In all of the case studies, agricultural water productivity measures contribute towards closing the water gap, increasing "crop per drop" through a mix of improved efficiency of water application and the net water gains through crop yield enhancement. These include the familiar technologies of improved water application, such as increased drip and sprinkler irrigation. The full suite of crop productivity measures includes, among others, no-till farming and improved drainage, utilization of the best available germplasm or other seed development, optimizing fertilizer use, and application of crop stress management, including both improved practices (such as integrated pest management) and innovative crop protection technologies.

In India, the least-cost set of levers—those on the left-hand side of the cost curve—is dominated by these agricultural measures, which can collectively close 80 percent of the gap and includes both irrigated and rain-fed crop production measures. In addition to the agricultural opportunity, lower-cost supply measures constitute the remaining 20 percent required to close the gap, delivered mostly through the rehabilitation of existing irrigation districts and the "last-mile" completion of earlier projects such as canals. The total annual cost for the combined set of supply and agricultural levers is approximately $6 billion per annum—just more than 0.1 percent of India's projected 2030 GDP. This analysis does not take into account implementation and institutional barriers, nor the impact on labor markets, GDP or other economic metrics, yet provides the starting point from which to consider approaches to overcome such barriers.

Efficiency in industry and municipal systems is similarly critical. In China, although agriculture still makes up more than 50 percent of the total demand, industrial and urban water uses are the fastest growing (at ~3 percent per annum). China can mitigate this rapid growth in a cost-effective way by instituting aggressive, water-conscious, "new build" programs and enacting water-saving regulatory reforms. If it does so, the cost to fill the gap is negative, implying net annual savings of approximately $22 billion. Most of the cost-saving levers on the left of the cost curve for China are industrial efficiency measures. These have the potential to close a quarter of the gap and result in net savings of some $24 billion. They are distributed among the thermal power, wastewater reuse, pulp and paper, textile, and steel industries. Their savings potential derives from significant savings in energy and other operational expenditures, translating into overall productivity gains. The net capital expenditure to close the remainder of the gap amounts to $8 billion, or less than 0.06 percent of projected 2030 GDP.

Quality and quantity of water are tightly linked. The least-cost solution in São Paulo state has a net annual cost of $285 million (0.04% percent of the state's projected 2030 GDP), a large part of which is in efficiency and productivity measures, while a supply infrastructure solution would nearly double the cost to $530 million per year, or 0.07 percent of GDP. Any approach to solving the state's water management challenges must consider resolving quality issues, both for practical usage reasons and for environmental reasons. Industries can generate significant financial benefit from reducing their water use via levers such as spring-valve installation and sensitivity sensors. Utility leakage reduction can save nearly 300 million m^3. Wastewater reuse for gray-water purposes (such as industrial processes and public works uses) offers roughly 80 million m^3 in new water.

Most solutions imply cross-sectoral trade-offs. South Africa has a balanced solution with cost-effective measures available across supply (which can close 50 percent of the country's projected supply-demand gap to 2030), agricultural efficiency and productivity improvements (30 percent), and industrial and domestic levers (20 percent). Seven river sub-basins are almost entirely dependent on agricultural improvements, while the economic centers of Johannesburg and Cape Town are dominated by industrial and domestic solutions. Almost 50 percent of the levers involve significant savings of input costs, effectively making half of the solution "cost-negative". In the case of industrial levers (such as paste-thickening and water-recycling in mining, and dry-cooling, and pulverized beds in power), up to $418 million in annual savings can be captured from the pursuit of efficiency.

4

Putting solutions into practice: New dialogue among stakeholders

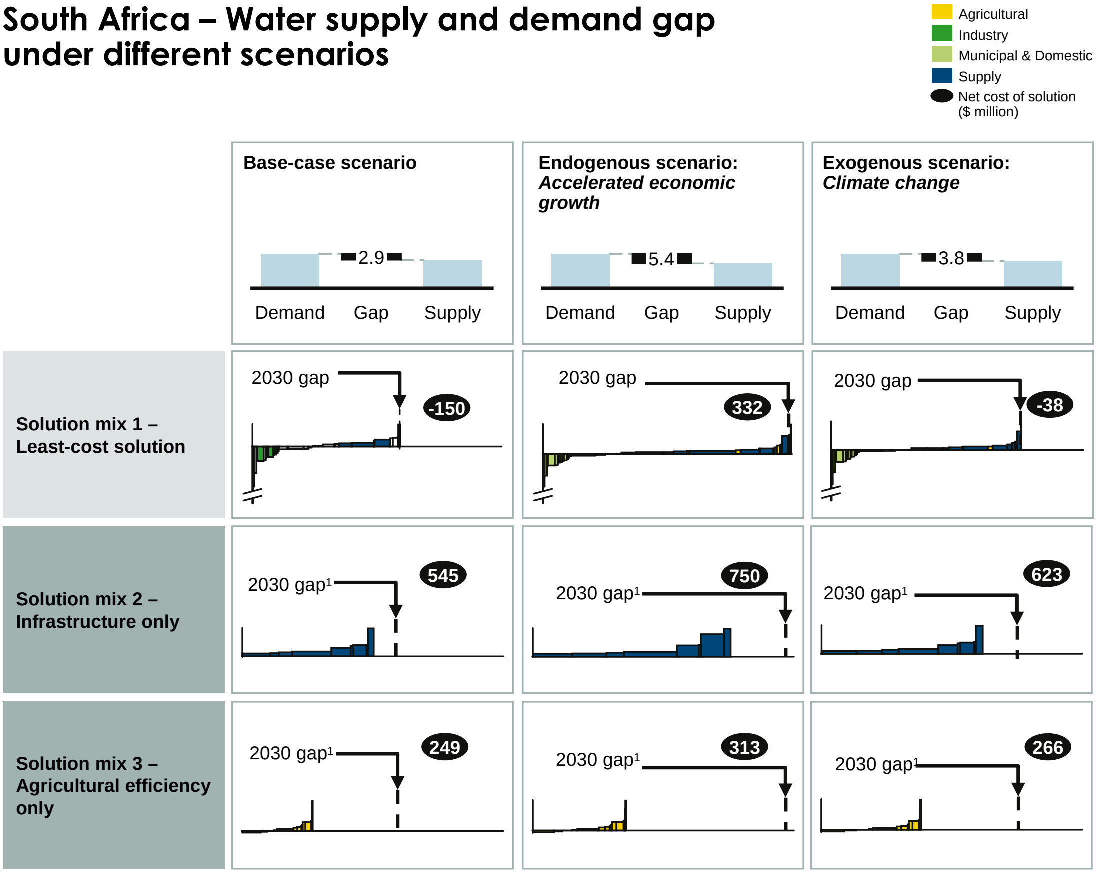
Knowing the least-cost portfolio of technical solutions that will close a country's "base-case" water gap is a significant step forward. On the way towards real change however, the technical options of new supply or better efficiency must be compared to additional options to shift the set of underlying economic activities away from the most water-intensive ones, recognizing that growth in energy, agriculture, and manufacturing have real implications for the water budgets of river basins and countries. The reverse is also true: planning for water must be integrative with directions of the whole economy, whether explicitly constrained by water considerations or not. Using an iterative process, governments and other key stakeholders in a given country can create a matrix of options from which to chart pathways of development that balance water supply and demand.

The tools developed in this report, including the cost curve and gap models, can help provide critical insights for those engaged in transforming a national water agenda. In such a transformation effort, the first step in applying these tools is to construct a set of future scenarios that represent relevant choices facing the country—these might include, for example, the water demand implications of rapid agricultural development; or those of reduced water availability a result of climate change. A scenario approach is chosen because it allows decision-makers to separate the problem of choosing an appropriate mix of economic activities, something that can only partly be planned and that is subject to large number of economic considerations, from ensuring that those economic activities are sustainable. For each scenario, a cost curve can then be constructed. Each cost curve can be used to define a set of technical solutions—a solution mix—such as the least-cost set of solutions, or the infrastructure-only set of solutions. A full suite of options, with the water costs associated with them, is therefore laid out for decision-makers to compare and discuss (Exhibit VI).

In choosing scenarios, and to some extent the technical measures to close the gap projected under any one of those scenarios, the trade-offs decision makers will face go well beyond the issue of water: they will need to consider everything from the impacts on growth and jobs (including geographic distribution), to the implications for trade and geopolitics. A decision cannot be taken solely on the basis of the quantitative water calculations described in this report, but the tools presented here will make the critical elements of those trade-offs more transparent and will define the boundaries of discussion well beyond the confines of the traditional water sector.

Exhibit VI

South Africa – Water supply and demand gap under different scenarios



1 The solution is insufficient to close the entire gap. Additional measures are required.
SOURCE: 2030 Water Resources Group

If all stakeholders are able to refer to the same set of facts, a more productive and inclusive process is possible in developing solutions. There are, of course, additional qualitative issues that need to be addressed, including institutional barriers (such as a lack of clear rights to water), fragmentation of responsibility for water across agencies and levels of government, and gaps in capacity and information. While the quantitative tools discussed here will not in themselves address these challenges, they *can* help highlight those areas where institutional reform or capacity-building are most needed in order to close the water deficit cost-effectively.

Because this process weighs a broader set of benefits and policy decisions against the technical costs of closing the gaps, each stakeholder group will have different angles and interests to keep in mind. It is by balancing these angles that a shared solution can be developed.

Each group of stakeholders can derive specific planning benefits and insights from using this approach, addressed in turn below..

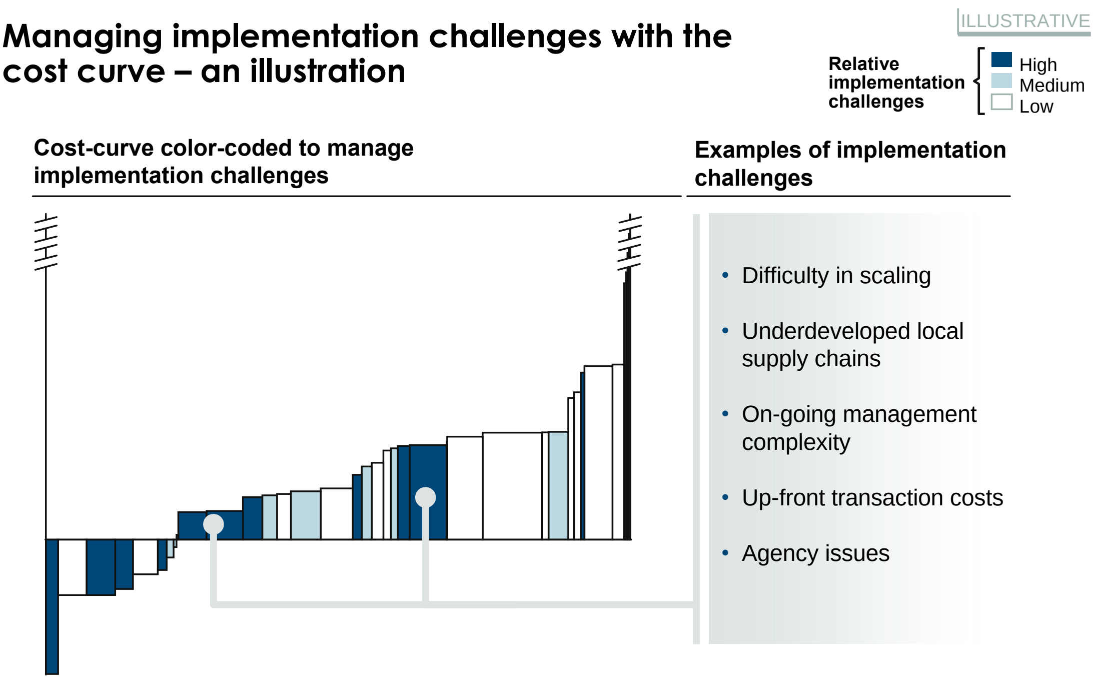
Tools for policymakers

Policymakers will want to assess whether the cost curve can reflect either the difficulty of implementing a technical solution which along with other secondary impacts will inform their policy choices; they will want to understand the impact specific water policies may have on the adoption of measures; and will want to understand which types of policies may change the adoption economics. Accordingly, three refinements of the cost curve approach can help policymakers understand how to mobilize solutions.

First, the measures on the cost curve can be **classified according to factors** influencing their ease of implementation, such as low institutional capacity, policy and cultural barriers, and the high number of stakeholders from whom action would be needed (Exhibit VII). Solutions that are in principle technically feasible may face one or more of such barriers, which—while not easily quantified in financial terms—are nevertheless very real for those charged with encouraging implementation. Policymakers can use the cost curve to understand the financial trade-offs implied by different levels of commitment to tackle such implementation barriers.

Exhibit VII

Managing implementation challenges with the cost curve – an illustration



SOURCE: 2030 Water Resources Group

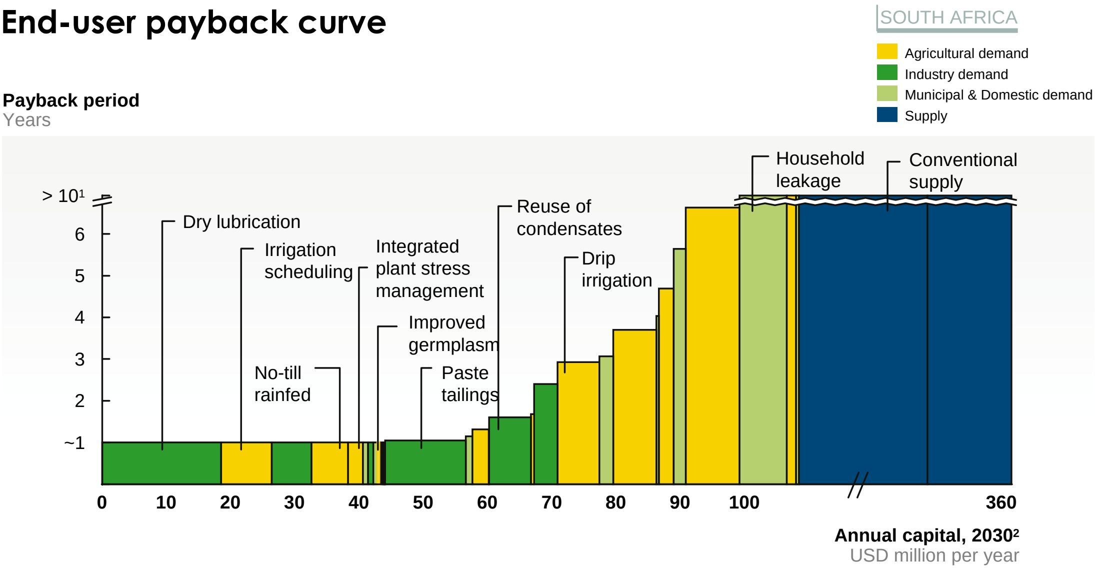
In China and India we grouped the levers, independently of economic "sector", according to whether their adoption required few or many decision-makers, taking this as one illustration of "ease of implementation" from a public policy perspective. The result of such an exercise can help to quantify the costs of not pursuing certain sets of measures. The exercise exposed the reality that a solution made up only of those measures which required the action of a few central decision-makers would come at significantly greater cost than a solution incorporating all available measures, including those whose adoption would require changed behavior from millions of farmers and industrial or domestic water users. Avoiding these "more complex" levers and applying only the "less complex" levers would require an additional $17 billion a year in capital costs in India, while in China the full gap could not be filled at all using supply measures currently within reach—a high price for forestalling the institutional and organizational reforms needed to enable the least-cost solution. This is just one illustration. The real value of classifying levers in this way is as an aid to collaboration with the very policymakers who must make the difficult trade-offs on the path the water resource security, and who will have deeper and more nuanced views of what the barriers to implementation might be.

Second, policymakers can construct **scenarios to assess the impact of policy decisions on water demand**. A policymaker will want to know how a country's projected water supply-demand gap would change when specific policy measures are enacted, or if greater-than-expected economic growth were achieved. The cost curve can reflect a range of different policy and growth scenarios. For example, a number of studies suggest that reducing energy subsidies in India—which currently allow farmers to pump groundwater at very low cost—would reduce crop production, which would in turn lower irrigation water needs. An assumed 5 percent decrease in irrigated crop production would reduce water demand by 8 percent—both straightforward calculations—but our analyses show the actual cost to close the resulting gap would be reduced by 10 percent. This is to be weighed against the reduced output in crops and the corresponding reduction in economic activity. An ethanol boom in Brazil would double the demand for water for agriculture in São Paulo state, and increase the size of the state's supply-demand gap from 2.6 to 6.7 billion m^3. As a consequence, the cost to close it would also double if relying upon the most efficient solution, and increase even more if supply measures only are prioritized.

Third, a "payback curve" can be developed to **quantify the economics of adoption for end-users**. The costs of measures to close a country's water supply-demand gap as seen by the end-user can be quite different from those perceived by government. The payback curve, a variation of the cost curve, can help (Exhibit VIII). It shows how long it will take for an investment to bear fruit, allowing comparison with the end user's expectations: a low-income farmer might need his money back in less than 3 years, whereas an industrial water user has more flexibility. Making financials more transparent can help policymakers distinguish between those measures that need an extra push, and those that, on paper at least, are financially attractive to the end-user. In India and China, for example, almost 75 percent of the gap could be closed with measures offering payback time of 3 years or less. São Paulo state, on the other hand, relies heavily on supply and efficiency measures that are not yet sufficiently attractive to adopters—86 percent have payback times above 5 years.

Exhibit VIII

End-user payback curve



1 Measures with no payback (i.e. only negative cash flows) also shown as > 10 years
2 Does not include financing cost
SOURCE: 2030 Water Resources Group

Pathways for the private sector

Governments are not the only stakeholders that matter, nor are they the only ones that need help managing water decisions. We outline a path forward for five specific private sector players who can contribute to water security solutions.

Agricultural producers and other agricultural value chain players. Food production and the water it requires are a key part of the water challenge. Food self-sufficiency in countries with rapid population and income growth will become an increasing challenge. Some 70 percent of the world's water use is in agriculture—with the implication that farming plays a very important role in ensuring water is available for all uses. The agricultural water solutions shown in the cost curves address both the water challenge and the food challenge, and represent the full suite of existing techniques and technologies that can improve agricultural productivity. The magnitude of the potential impact of these solutions on both challenges should motivate farmers, other agricultural value-chain players (e.g. food processors), and policymakers to jointly address their implementation. In India, where agriculture plays the most important role in the least-cost solution, aggregate agricultural income could increase by $83 billion by 2030 from operational savings and increased revenues, if the full potential of agricultural measures is mobilized. In South Africa, where agriculture contributes 30 percent to the least-cost solution, the aggregate potential is $2 billion. Though we have focused on measures that can be implemented geographically close to production, the opportunity exists to reduce losses and therefore "save" water and other inputs throughout the value chain.

Financial institutions. There is wide agreement that water has suffered from chronic under-investment. Financial institutions are likely to be an important actor in making up this shortfall. The cost curves provide such institutions with transparency on the financial costs and the technical potential of measures in the long run to close the water supply-demand gap, as well as on the barriers to their adoption, thus helping them construct credible investment theses—particularly important at a time when credit is hard to find. Investment opportunities span all sectors—the measures that in aggregate require the most capital in each country are municipal leakage reduction in China, and water transfer schemes in São Paulo and South Africa. In India, drip irrigation offers potential for lending and equity investments alike: our analysis implies that the penetration of this technology will grow by 11 percent per year through 2030, requiring increased manufacturing capacity and credit for farmers.

Large industrial water users. The nexus between water and energy, and between water quantity and quality, is at the heart of the water challenge, as we have seen in China and Brazil. Industry faces a potential spiraling challenge of decreasing water resources and increasing pollution, both requiring increasing energy. These issues are particularly relevant to large industrial users such as metals, mining, petroleum, and energy companies, who face both a water and an energy challenge. The transparency provided by the demand and supply analysis and by the cost curves on where such companies' exposure to the risk of water scarcity is greatest, and what their options are to mitigate the risk, will assist them in making the case for investing in water efficiency solutions. In South Africa, for example, the basins with the largest gaps are also the centers of industrial water demand: In the Upper Vaal, where industry makes up 44 percent of demand, the gap is 33 percent, in Mvoti-Umzimkulu (where industry is 25 percent of demand) 46 percent. In such cases, the risk of water scarcity may affect the choice of technology, pointing towards potential measures such as dry cooling and fluidized-bed combustion in power generation, and paste tailings in mining.

Technology providers. Innovation in water technology—in everything from supply (such as desalination) to industrial efficiency (such as more efficient water reuse) to agricultural technologies (such as crop protection and irrigation controls)—could play a major role in closing the supply-demand gap. Also, many of the solutions on the cost curves developed for each country imply the scale-up of existing technologies, requiring expanded production on the part of technology providers. The cost curves provide a framework that technology providers can use to benchmark their products and services for an estimate of their market potential and cost-competitiveness with alternative solutions. Membrane technology, for example, is still 2-3 times more expensive in China than traditional treatment technologies. As the need for high-quality water treatment increases, specifically for potable or high-quality industrial use or re-use, low-pressure membrane technology could develop a market potential of up to 85 billion m^3 by 2030, 56 times its volume in 2005.

Construction sector. A renewed interest in efficiency and productivity does not mean that supply measures do not have an important role to play, as we have seen in Brazil and China. The construction sector will need to continue to deliver that large-scale infrastructure. The cost curves provide transparency on where such infrastructure is most needed, and where alternative solutions may prevail. In South Africa and Brazil, for example, supply infrastructure makes up some 50 percent of the gap. Even in India, where the share is only 14 percent, the required annual investment still amounts to $1.4 billion per year.

5

Unlocking water sector transformation

Business-as-usual in the water sector is no longer an option for most countries. The beginnings of change are under way and there is good reason to believe that water will be an important investment theme for public, multilateral and private financial institutions in the coming decades. Although affordable solutions are in principle available to close the projected water supply-demand gaps for most countries and regions, institutional barriers, lack of awareness, and misaligned incentives may stand in the way of implementation, across both the private and public sectors. Overcoming these barriers will require persistent action and, in many cases, an integrated agenda of water sector transformation.

This report is founded on the belief that developing a fact-based vision for water resources at the country or state level is a critical first step in making a reform agenda possible. This vision will help identify metrics, such as the supply-demand gap, or the potential of different measures, that can help to measure progress. It will link cost and economic data to water resource data—including environmental requirements—a step which is essential to manage the water challenge. Without such a vision, it will be difficult for leaders to gain support for more rational management decisions on water resources. Because of the cross-sectoral nature of the analysis, linking such a vision to action requires high-level energy and support, and commitment from the most senior decision-makers in the country. In countries with sufficient resources, existing institutions can be empowered to produce the data needed to inform such visions. In countries with limited resources to manage their water sectors, developing this data should be a high priority for those seeking to assist.

Having created the fact base and gone through the process of describing the options available, policymakers, the private sector and civil society will need to come together to put into practice a transformation towards sustainability. The fact base can provide crucial guidance for this process at several levels.

For example, an understanding of the economics of the chosen solution will help decision-makers come to a rational design of the economic regimes within which water is regulated. In this regard, there is considerable experience on the way market mechanisms can help efficient use of water by businesses and cities. Further, identifying the barriers to adoption, and the implementation challenges inherent in the measures described on the cost curve, will help leaders focus and improve the institutions needed to champion and implement reforms. The cost curve also provides a benchmark of existing technologies and their cost to deliver additional water, providing guidance for investment in technology hubs, research and education to unlock future innovations in the water sector. Such innovation will be critical in generating new options and reduce costs of provision.

By demonstrating which measures have the greatest impact in delivering solutions, a robust fact base can also spur focused financial investments from the private sector as a key engine for reform. A number of approaches exist, from public/private water financing facilities, to public projects that create the space for private financiers to scale-up their investments, to innovative, microfinance solutions for end-users. Policymakers, financiers, conservationists, farmers, and the private sector need to cooperate to develop and promote innovative financial tools to ensure those willing to improve their water footprint are given the opportunity—and capital—to do so.

In many cases large individual water users have a big role to play in managing demand. Government policy can help align industrial behavior with efficiency objectives, forming a key component of a reform program. It is critical to ensure incentive design emphasizes the value of water productivity—for example through clearer ownership rights, appropriate tariffs, quotas, pricing, and standards—and at the same time recognizes the impacts such incentives can have on the companies' profitability. A fact base on the economics of adoption and on the real potential of efficiency measures in such sectors can help identify and prioritize the right regulatory tools for action.

* * *

The case for prioritizing country-wide changes in water resources management has never been as strong. We have seen that the challenges that lie ahead are considerable for many countries. But we have also provided evidence that none are insurmountable.

We hope the information presented in this report further enriches the global debate, and provides policymakers, business stakeholders, civil society and public users with the tools they need to unlock the full potential of a sustainable water economy.

Introduction

Over the past 50 years the world's population has doubled and global GDP has grown tenfold, agricultural and industrial output has boomed, and cities have burgeoned. This growth, and these competing uses, have put global water resources under ever-increasing strain.

Yet despite the depletion of watercourses, glaciers, and aquifers in many regions, the Earth is not running out of water—in fact, most countries have more than enough water to supply their populations' growing needs *and* to sustain the flows needed to protect the natural environment. The problem, rather, is that our societies are doing a poor job of managing these water resources. The rate of innovation and productivity improvement in water resource management lags that of many other sectors. It is this management challenge—a factor that we as human societies can control—that threatens our economies, human life and health, and natural ecosystems. We are not simply at the mercy of a scarce and variable natural resource.

The 2030 Water Resources Group came together in 2008 to contribute to finding solutions to this challenge. The Group is co-led by the International Finance Corporation and McKinsey & Company, and comprises a business consortium made up of Barilla, The Coca-Cola Company, Nestlé, New Holland Agriculture, SABMiller plc, Syngenta AG, and Standard Chartered Bank. The effort has relied on the expert input of a range of leading scientific, multinational, and nonprofit institutions. *(See page ii)*

This, then, is a study focused on water resources—sponsored, written, and supported by a group of private sector companies and institutions. Why? Because growing competition for scarce water resources is a growing business risk, a major economic threat that cannot be ignored, and a global priority that affects all sectors and regions. It is an issue that has real implications for the stability of the countries in which businesses operate and the sustainability of communities and the ecosystems they rely upon. Industries whose value chains are exposed to water scarcity face an immediate threat. In this context, private sector stakeholders have a responsibility to engage actively in solutions to the water challenge—sitting on the sidelines is not enough.

Growing engagement of private sector institutions is a clear sign of greater global attention to water issues. The UN CEO Water Mandate, the Global Water Partnership, the World Business Council for Sustainable Development, the World Water Forum, World Water Council, and the World Economic Forum's Global Agenda Council on Water, among others, are important public forums for this engagement. Professional organizations also are important bodies for pushing thinking on technology and management of water. This report is intended to push that engagement one significant step further, and generate additional practical approaches and methodologies that public, private and civil society decision-makers can use to help countries manage their water resource sustainably.

One important precedent for this report has been the application of economic tools, also developed by private sector institutions, to carbon abatement strategies.[1] Such tools have been used to quantify an abatement or availability "target", driven by economic and social growth, and to construct a marginal cost curve that estimates the impact of a wide range of possible interventions to meet that target. There are of course fundamental differences between carbon abatement and water provision—for example, the local nature of water challenges vis-à-vis the

1 *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve*, McKinsey & Company, 2009

nature of the atmosphere as a global commons. But, as in the case of carbon, there is value in providing a standard, quantitative language on water that can bring stakeholders around a shared table to reason, in a fact-based way, on the challenge of managing the most precious of resources.

The Group's core contribution, then, has been to develop a systematic framework that can be used to shed light on the economics of water and evaluate water resource solutions at the country level. To those familiar with the water challenge, our endeavor might appear daunting, as the quality of the data is highly variable and often uncertain. We fully acknowledge these uncertainties and welcome contributions that can improve the accuracy and usefulness of this work through better data. But, as private sector organizations accustomed to making investment decisions under conditions of uncertainty and change, we believe that a first, approximate map in a time of need is better than no map at all.

At its core, this report is an effort to offer comparative insights on the technical and economic dimensions of water resources across and within multiple countries. These insights can inform stakeholder discussions and enable more effective policy development and decision-making on country-level water challenges. Although the fact-base presented in this report is policy-neutral, is does create transparency on the cost of inaction in dealing with water scarcity issues, and is thus likely to add impetus to water sector reform efforts.

A caveat is warranted. This work is a starting point, not a solution to all water problems. We fully recognize that water is a heterogeneous good and a complex sociopolitical issue and we acknowledge the vast body of economic and political economy literature that has elaborated on the subject. This report does not intend to substitute for that work. Rather, it provides the beginning of an approach and a methodology that can be adopted, refined and built upon to help countries manage one of their key natural resources.

This approach and methodology—along with the findings and insights generated to date—are presented in five chapters:

Chapter 1, "**Shining a light on water resource economics,**" outlines the central problem—a lack of clarity on the economics of water resource planning, leading to under-investment and inefficient use—that has prompted the Group's initiative; and it sets out the key steps undertaken in the effort.

Chapter 2, **"Managing our way to scarcity: The challenge ahead"** quantifies the gap between projected water requirements in 2030 and currently available supply, and paints a picture of the water crisis that lies ahead if "business as usual" water management practices continue, both globally and in four key countries in which case studies were conducted.

Chapter 3, "Toward solutions: An integrated economic approach to water resource management," demonstrates that water resource security *can* be achieved cost-effectively, and lays out an integrated economic approach that countries can follow to identify solutions balancing supply expansion, water productivity improvement, and changes in underlying water-using activities. The chapter outlines potential solutions for each of the case study countries.

Chapter 4, **"Putting solutions into practice: New dialogue among stakeholders,"** discusses how the tools presented in this report can be used to envision alternative scenarios of water supply and demand, and use such scenarios to mobilize stakeholders—including agricultural, industrial and household end-users and public and private investors—whose participation is needed to come to a more sustainably managed water sector.

Chapter 5, **"Unlocking water sector transformation,"** argues that achieving water resource security will in many cases require an integrated program of water sector reform at the country or state level, built on a robust fact base. The chapter discusses the key elements of such a program, including shaping new policy interventions, transforming institutions, and incentivizing investment in and adoption of solutions.

A substantial appendix provides acknowledgements of the extensive family of local and international experts consulted during the project, a full list of abbreviations and glossary of terms used, additional descriptions of methodological approaches and technical measures assessed, beyond those given and selected references.

Chapter 1
Shining a light on water resource economics

> Water resource availability: Defining the challenge

> The murky economics of water resources

> Creating clarity, unlocking solutions

> New economic tools for water

This chapter defines the scope of the report—water resource availability—and describes the worsening imbalance between water supply and demand at basin and national levels. It then sets out the approach taken by the 2030 Water Resources Group in finding solutions to this challenge, outlining the suite of economic tools developed and applied in this study.

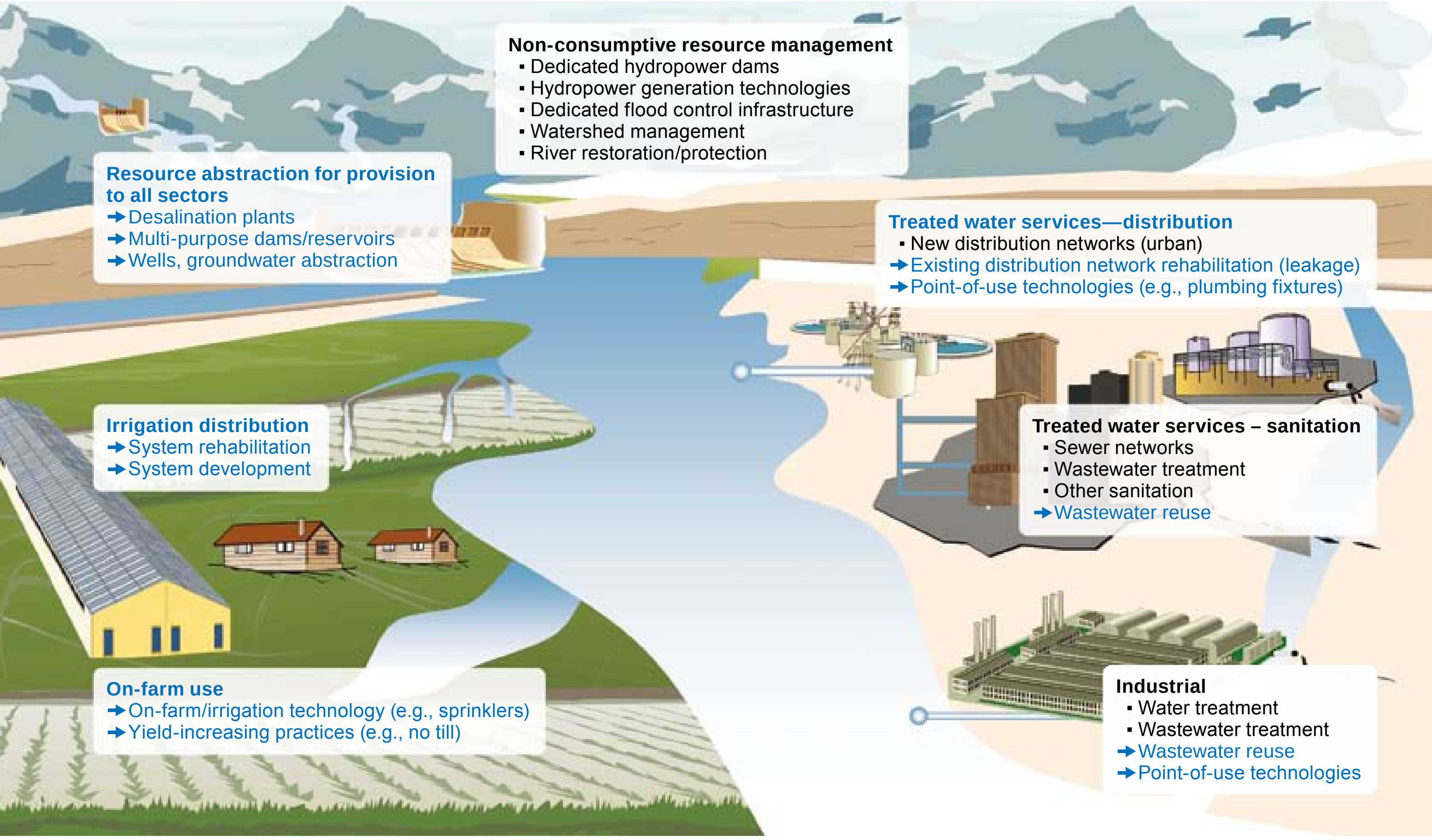
Water resource availability: Defining the challenge

Water resource management can refer to a number of activities addressing the impact of water use on economic activity, people, and the environment. These could range from protection against the destructive elements of water (flood control), to ecosystem protection, to hydropower and navigation uses, to activities that divert water resources for consumptive use. The focus of this study, however, is strictly on the latter: water resource availability for consumptive uses, with particular attention to areas where limited water resources create competition among different sectors such as agriculture, industry, and municipal or domestic uses (Exhibit 1).

Exhibit 1

Our focus is on water resource availability at the basin scale

Water technologies in ***blue*** are relevant to water resource availability and this report



Activities relating to consumptive use of water resources can generally be thought of either as "upstream" or "downstream"—or perhaps more appropriately for water, activities that impact resource availability or those that provide treated water services. This study, then, focuses on the "upstream" elements of the water challenge, including:

- **Capturing and abstracting water**—for example, through dams and reservoirs or groundwater pumping

- **Conveying water** to a demand center—for example, via agricultural canals

- **Increasing water resource availability** by improving the **efficiency of water use** in sectors such as power generation, agriculture, and municipal uses—for example through dry cooling in power plants, or drip irrigation in agriculture, all of which can result in reduced net withdrawals

The study does not cover the "downstream" elements of water—provision of treated water services, including water purification to some level of quality, delivery of treated water to the end-user and subsequent wastewater treatment. This choice of focus is not to discount the critical importance of these "downstream" elements—indeed, more than a billion people lack access to clean drinking water. But securing "upstream" water resource availability is a prerequisite for having sufficient water to treat and distribute. It is also a fundamental social issue in its own right: competition for scarce resources within and between countries can have profound social, economic, and political consequences. For example, consider the impact on social stability if the next drought forces a choice between supplying water to large-scale plantations or to smallholder irrigation. Alternatively, whether enough water is available for mining and riparian wetlands when irrigated cotton farming expands upstream, can force hard trade-offs on economic development. In areas where the conflict of competing consumptive uses is acute, there are always losers—frequently the poor and the environment.

Addressing the water availability challenge requires a shift in thinking about the expenditures required. Annual expenditures on the part of the water sector that impact resource availability amount to between $70 billion and $90 billion worldwide (see Box 1: Reconciling different perspectives on the "water sector"), including capital and operating expenditures for raw water and upstream resource abstraction, as well as technologies to improve the efficiency of water use in industrial, commercial, and household use. Our analysis—and our calculations on the expenditures required—are based on the view that water resource availability measures should be defined more broadly to include steps such as agricultural yield improvements that, while not specific to water, may increase water productivity. Such measures have the effect of conserving water resources, thus increasing water availability for other uses.

BOX 1

Reconciling different perspectives on the "water sector"

How should the water sector be defined, and how should its annual expenditure be estimated? The water sector is seen from several quite different perspectives, leading to confusion on what constitutes the "water market" and what level of investment is needed. The perspective adopted for the purposes of our economic analysis emphasizes raw water resource availability at the basin level. Annual expenditures on this "upstream" part of the water sector amounted to between $70 billion and $90 billion worldwide in 2005[2]—including capital and operating expenditures for resource abstraction, agricultural irrigation technology, and water reuse. Technology to use water more productively anywhere in the economy would also be included in this perspective, given its role in reducing the water demand of particular sectors and hence increasing availability for other uses. Likewise, water re-use technology is included in this perspective, as it also decreases the net withdrawals of water.

The traditional perspective on the water sector emphasizes downstream water supply and sanitation, as well as industrial use. (Upstream resource abstraction is partially included, usually only for supply measures for municipal needs only). Under this perspective, total expenditure across the sector is estimated at $485 billion worldwide in 2005.[3] This number comprises all capital and operating expenditures to provide water and wastewater services, including engineering, planning, and construction (EPC), technologies (pumps, pipes, valves, filters, membranes, etc.), and other input costs. Expenditure by utilities accounts for 70 percent of the total, with the remainder split between industrial technologies, mostly for effluent treatment, and domestic applications such as purifiers. The water sector thus defined excludes on-farm agricultural productivity, institutional support, and non-consumptive resource management (for example, flood controls and dedicated hydropower that is not used for water provision). By 2016, annual expenditure in the traditional water sector is projected to grow to $770 billion, with growth primarily in the water supply and sanitation sector. This figure is comparable to expenditures in other utilities: for example, today's global expenditures in the natural gas sector amount to around $770 billion annually, and in the electricity sector to some $1.5 trillion.[4]

From the perspective of development aid agencies, the water sector in developing countries—including expenditures on rural and urban water supply and sanitation as well as raw water abstraction—is valued at some $65 billion to $80 billion annually.[5] These numbers are not directly comparable to the ones above, as they include expenditures excluded in the traditional

2 Estimated from several sources, including reports from Global Water Intelligence, the World Bank, and World Water Vision. Though yield-increasing agricultural inputs are important for reducing water withdrawals in the future, we did not include the entire global market in these calculations.
3 Global Water Markets 2008, Global Water Intelligence
4 Datamonitor, Electricity: Global Industry Guide, 2009
5 World Bank, World Water Vision, World Water Council

view; these figures are often quoted in the context of the Millennium Development Goals (MDGs), which emphasize expansion in access to water services and sanitation in developing countries. They also do not include annual operating costs. Reports issued by the World Water Council[6] and others argue that if MDGs are to be met, annual investments in the order of $180 billion will be required to 2025 (although even the achievement of the MDGs will still leave many without safe water access).

Exhibit 2 compares these three perspectives and maps out the full range of possible definitions of the water sector.

6 "Financing Water for All": Report of the World Panel on Financing Water Infrastructure, World Water Council (2003) ["Camdessus report"]

Exhibit 2

Different views of the water sector

2007 expenditures, USD billion

Category of expenditure		Sub-categories	Traditional water view[1] (Capital, Operating)	Development aid[2] view (Capital, Operating)	Water resources view (this report) (Capital, Operating)
Non-consumptive resource management		▪ Dedicated hydropower dams ▪ Hydropower generation technologies ▪ Dedicated flood control infrastructure ▪ Watershed management ▪ River restoration / protection		7	
Upstream resource abstraction		▪ Desalination plants ▪ Multi-purpose dams/reservoirs ▪ Wells, groundwater abstraction	12	33 (spans upstream resource abstraction and agriculture distribution)	40-45 (spans upstream resource abstraction and agriculture distribution)
Agriculture	Distribution	▪ Irrigation system rehabilitation ▪ Irrigation system development			
	On-farm use	▪ On-farm/irrigation technology (e.g., sprinklers) ▪ Yield-increasing practices (e.g., no-till) ▪ Yield-increasing inputs (e.g., fertilizer)	9		10-15 *
Industrial	Treatment	▪ Water treatment ▪ Wastewater treatment	24	~ 7	
Downstream water supply & sanitation	Treatment	▪ Water treatment plants, technologies	430 (spans treatment, distribution & use, and sanitation & treatment)		
	Distribution & use	▪ New distribution networks (urban) ▪ New distribution networks (rural) ▪ Existing distribution network rehabilitation ▪ Packaged water ▪ End-user technologies (e.g., plumbing fixtures)		13	10-15[3]
	Sanitation & treatment	▪ Sewer networks ▪ Wastewater treatment ▪ Wastewater re-use ▪ Other sanitation		14 1	10-15[3]
Institutional support		▪ Capacity building; institutional support			
		Total	~485	~75	70-90

1 Included when specifically relevant to increasing potable supply for consumptive reuse; estimated at 10% of total wastewater treatment
2 Data from 2007, Global Water Intelligence Market Report 2008
3 Data from Camdessus/GWP 2002
* Not estimated
SOURCE: 2030 Water Resources Group

The murky economics of water resources

It is now well established that population and economic growth are placing water resources under increasing strain. Major regions of the world will face a massive water challenge the coming decades if current trends continue—with potentially devastating consequences for human life and health, business and agriculture, international relations, and the environment if they do not adapt.[7] There is also considerable evidence that climate change could lead to worsening water scarcity in many countries.

In principle, however, most countries have more than enough water to supply their populations' growing needs and to sustain their environmental flows. What is missing is a way of integrating decisions on water management into the full set of economic choices a country needs to make. Governments, as well as businesses in sectors as diverse as agriculture, power generation, and manufacturing, know that water is central to their economic activities, and yet management of the resource is generally undertaken in isolation from overall economic strategy. Today, many countries typically plan for development and growth assuming that water will be available when and where it is needed—and that the water sector will simply catch up with the rest of the economy. However, the water sector is not catching up.

Many voices call attention to the fact that the water sector is severely under-funded,[8] with especially serious financing gaps in developing countries.[9] While under-investment in the water sector represents a looming problem for many economies, it is not a surprising outcome: investors, both private and public, lack a consistent basis on which to make economically rational investment decisions and therefore the will to invest in the sector. And the lack of clarity on the true financial cost of water exacerbates the problem in a further, important way: businesses, farmers, and households lack sufficiently strong signals and incentives to prompt them to use water more efficiently and productively.

Water's murky economics have also had a negative impact on the debate about solutions, all too often narrowing it to a technical discussion within the water sector and among water experts. In fact, there is not even a commonly accepted framework or language to describe in quantitative terms how a country might go from unsustainable to sustainable practices. While water resource planners at the local level have many of the required tools available to them, country-wide assessments are seldom undertaken to calculate the future demand for water and to understand the implications for infrastructure and economic activities. An explicit analysis of the impacts on the water system of choices in trade, urbanization, and growth is rare at best, even for water-scarce countries. Likewise, an assessment of the full cost of water provision is often unavailable, with the true number buried under subsidies, taxes, and sunk costs of municipal and regional water departments.

7 See, for example, "Water for the Changing World," UN World Water Development Report 3, UN (2009); "Water for food, water for life: A comprehensive assessment of water management in Agriculture," IWMI (2007); and "Saving Water: Field to Fork," IWMI/SIWI (2008)

8 See, for example, UN Water Development Report 3 (2009): "Water for the Changing World," "Financing Water for All: Financing Water for Agriculture," (Gurria Report), WWC/GWP; "Water Resources Sector Strategy," World Bank (2004); "Financing Water for All," (Camdessus Report), WWC/GWP (2003)

9 See, for example, World Bank, (Briscoe and Malik) (2006): "India's Water Economy: Bracing for a turbulent future"

Under these conditions it becomes almost impossible to manage water for consumptive uses, let alone manage its role as a shared public good. Because of the lack of clarity on the economics of water resource management, other important roles that water plays can fall by the wayside, including its role in ecosystem services (such as habitat preservation and flood protection).

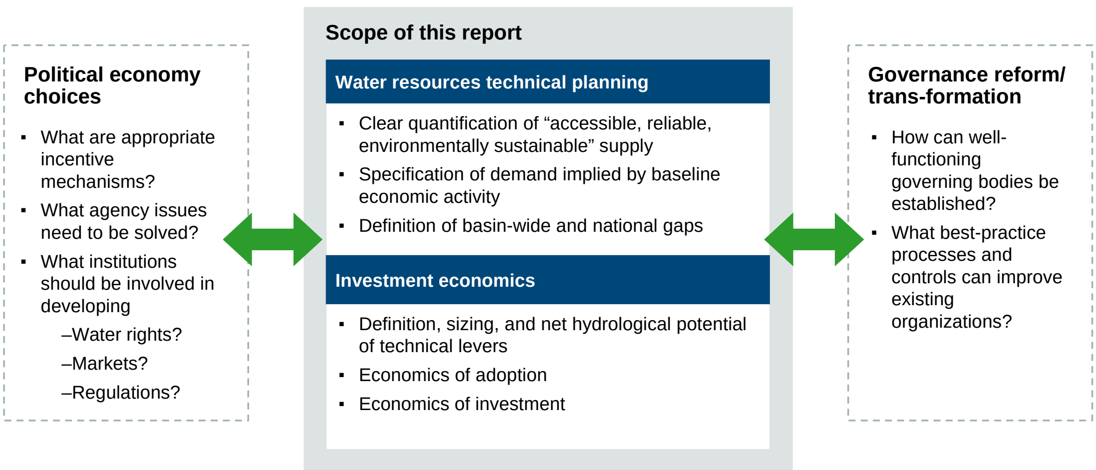
Creating clarity, unlocking solutions

The 2030 Water Resources Group came together to create a new level of clarity on the economics of water and to help unlock solutions to the water resource challenge. Our contribution has been to assemble an economic database and develop a systematic framework that can be used to shed light on the financial costs of water and evaluate water resource solutions at the country level—as a step toward creating sustainable, cost-effective paths to water resource security.

In helping countries construct an economic fact-base on water, our intention has been to link four aspects of water resource management that traditionally have either been dealt with separately or conflated to the point that comprehensive solutions are difficult to envision. At the center of the water management world lie water resources technical planning, engineering and hydrology, disciplines which deal with the basic balancing of water demand and supply, reliability and delivery, and conservation. Closely linked to this is the economics of investment in water initiatives: managing the economic and financial resources needed to implement the supply and other measures that water engineers and hydrologists prescribe. These two aspects should in turn be influenced by the political economy—the world of incentives, institutions, and water governance—where economy-wide trade-offs need to be made between different policy objectives. Finally, effective organizations are required to enable the delivery of solutions developed from a technical and economic perspective (Exhibit 3).

Exhibit 3

The world of water resources management



SOURCE: 2030 Water Resources Group

The approach discussed in this report, focused on the core water management areas of technical planning and investment economics, will enable policymakers and practitioners at the country level to tie these different components together through a shared, fact-based understanding of the problem. Further, it creates a common language that decision-makers and stakeholders across the public and private sectors can use to discuss both the financial costs and the impact of measures to achieve water resource security, as well as the cost implications of particular political economy and regulatory choices and trade-offs. The approach follows four steps:

1. **Quantify the impact of economic and social growth** on the use of a country's water resources, and assess whether the resources delivered by the country's existing infrastructure are capable of supporting its projected future water demand.

2. **Describe the financial costs and requirements of meeting future water demand,** thus creating a full picture of what the investment and resource requirements are for each country

3. **Compare different scenarios of growth** at a country level, involving different intensities of water use and different production patterns, to understand what trade-offs might need to be made (for example, reducing the cultivation of water-intensive crops in order to support urban and industrial growth) to achieve water security

4. **Describe the implications for stakeholders** for policymakers by quantifying the barriers to adoption and the impact policy levers can have on them, and for the private sector by identifying opportunities for action where businesses can deploy resources and capabilities.

We applied these steps in case studies undertaken in four countries and major regions with significant water resource challenges: India, China, the State of São Paulo in Brazil, and South Africa. Our intention is for the fact bases generated by these studies to lead to more productive dialogue in those countries among a broad set of stakeholders including policymakers, water resource scientists and engineers, and water users—including the private sector. We hope also that the fact bases, as well as the economic framework developed through this initiative, will contribute to the global water debate by directly linking policy choices to the impacts they will have on costs, the broader economy, and the environment. In this respect, our work builds on recent efforts toward an integrative consideration of water resources, such as the principles of Integrated Water Resources Management[10].

While our focus has been on creating clarity on water resource availability and the associated investment economics, as opposed to the entire set of water issues, we believe that this

10 The principles of Integrated Water Resources Management (IWRM) have been championed for over 10 years by the Global Water Partnership, a program established by the World Bank, the United Nations Development Programme (UNDP), and the Swedish International Development Agency (SIDA)

contribution can help catalyze real progress and build momentum towards solving several other crucial water problems. For example, more than a billion of the world's people lack access to safe drinking water. Increasing pollution and growing water use by industry and the power sector competing with agriculture and cities for the resource; dwindling water resources are leading to cross-border tensions; and wetlands and marshes are disappearing as water is withdrawn for human consumption. Building a pathway toward water resource security will provide countries with a foundation for addressing these additional, and crucial, water issues.

New economic tools for water resources

To create fact bases for the countries and regions under study, as well as a global picture of the economics of water resource management, the 2030 Water Resources Group developed a new set of tools to bring clarity to decision-makers and stakeholders.

Water resources tools

We developed two tools to quantify the gap between projected future water requirements and existing supply, and to evaluate the cost and impact of a wide range of possible measures to close that gap:

- A **global water supply and demand model** covering 154 basins and countries. This model allowed us to estimate the magnitude of the potential future water availability challenge for each country and basin, through a high-level examination of supply and demand drivers and constraints.

- A **national water supply and demand model with scenario analyses,** which we applied in the case study countries. The model was built with basin-level data as available, incorporating the main drivers of projected future water deficits and was used to create scenarios for future water demand to understand how different patterns of economic development would impact water resource availability.

These tools, and the findings they generated, are described in Chapter 2.

Economic tools

We also developed two tools to aid understanding of the economics of water resources:

- A **cost-curve of incremental water availability** to assess the potential and costs of a set of measures to close the projected deficit between water supply and water requirements in a given country or basin.

- A **"payback curve"** to evaluate the returns that any given measure would generate against the capital needed to fund it as perceived by the end user or adopter of a measure.

These tools, and their application to the case study countries, are described in Chapters 3 and 4.

Chapter 2
Managing our way to scarcity: The challenge ahead

> Projected water requirements vs. existing water supply: Sizing a future gap

> "Business as usual" approaches will not mobilize the required investments

> The impacts of global trends at the local level

To anyone familiar with recent water research, the finding that the world faces a looming water challenge will not be news. It is more difficult to quantify the size of that challenge. Current projections of population and economic growth imply that in 2030 global water requirements will be 40 percent greater than current supply—and that one-third of the world's population, mostly in developing countries, will live in basins where this deficit is larger than 50 percent. In a water sector historically plagued by under-investment, insufficient planning, and inefficient markets, such a gap is truly alarming; it is by no means a given that the sector will be able to course-correct to meet this challenge.

Using the tools described in Chapter 1, this chapter provides country-level estimates of the gap between the amount of water that can currently be provided, and the water requirements projected into the future under a static policy regime. It shows why "business as usual" approaches are unlikely to close this gap. Finally, it examines the water supply and demand dynamics in each of the case study countries, highlighting the distinct drivers of the projected supply-demand gap in each country.

Projected water requirements vs. existing water supply: Sizing a future gap

Sizing the challenge is the critical first step for identifying solutions—yet to date stakeholders and decision-makers across sectors have lacked a common toolset and fact base to quantify and cost the water resource requirements implied by economic and population growth. In planning for water provision, therefore, water managers must often make implicit assumptions about the trajectory of future water use in other sectors, the efficiency of that use, and the extent to which new supply can be added. On the other hand, public and private decision-makers planning for agricultural, industrial or urban growth will often make implicit assumptions about the amount of water that will be available in the future, often viewing the delivery of water as a technical matter rather than an economic challenge integral to their planning. Likewise, resource economists trying to model future water supply-demand equilibrium in the absence of explicit market mechanisms will have to guess the impact on supply and demand of hard-to-estimate shadow prices—that is, what individuals, companies, institutions will be willing to pay for an additional amount of water. The different assumptions and models used by these actors make a common, integrated view of the problem very difficult to attain.

We have not attempted predictions of future efficiency gains or supply increases, or made assumptions about the effectiveness of the mechanisms currently in place to match demand and supply. Rather, we have built our assessment from the ground up. We project what a country's or basin's water resource requirements would be if they were unconstrained and, under existing policy regimes, continued into the future at existing levels of productivity and efficiency, and then compare this projection to the supply of reliable, accessible water available today.

Our working definitions for water demand and water supply emerge from this approach. In the remainder of the report, we use *"water demand"* to refer to the concept shown above, that is, the unconstrained projection of water requirements under a static policy regime. The term *"water supply"* refers not to the raw resource itself, but rather the amount of raw water that is accessible to a demand center and can be delivered reliably and sustainably with respect to the environment or the finite resource base. For example, surface water that is currently withdrawn to the detriment of downstream environmental needs, or groundwater extracted that is not replenishable on reasonable timescales, would not be included as supply (for broader definitions of water resource supply see Box 2).

Projected future water demand and currently available supply, thus defined, will certainly not match: a gap, or deficit, will arise from future demand exceeding today's supply. The advantage of illustrating the water challenge in terms of such a gap is that it can provide stakeholders with a mechanism to isolate and diagnose explicitly the economic and social drivers likely to put the greatest pressure on the water resources of a country or basin. In some cases, the main contributor to the water gap may come from population growth alone via municipal uses, while in others it is driven primarily by growth in energy use. Such an approach shows the extent to which the balance between supply and demand will be required to adjust in the future, and motivates the investment and enabling policies needed to deliver that adjustment.

We should note that calculating the gap described above does not dynamically predict the real amount of supply and demand that will occur in practice in the future. Water efficiency improvements, additional supply, and changes in production in response to scarcity, will all contribute to closing the gap eventually. The critical question is whether, without explicit policy intervention, we should expect these developments to provide an optimal and cost-effective mix of solutions. If not, unmet demand will result, with explicit or implicit allocation essentially rationing water between uses; we explore this issue in Chapter 3.

BOX 2

How should water demand and supply be defined?

A working understanding of water resource demand and supply is a required point-of-departure for our analysis.

We use **demand** to refer to an unconstrained demand, or the projected water requirements if efficiency is unchanged and the policy environment is static. This demand is measured as the actual withdrawals from surface water, groundwater or nonconventional sources (for example, desalination). A portion of the withdrawn water may subsequently be available for other uses, depending on the time, place and quality of the "return flow". In defining water demand, the choice of focus on withdrawals differs from a focus on consumption, which is the net between the initial withdrawal and any return flows.

For water **supply**, we use a more technical definition, based on the natural constraints and infrastructural capacity. Total renewable water resource represents a theoretical upper limit for what can be abstracted from the natural system, whether from surface water or groundwater. The problem lies in translating this total resource into "accessible, reliable, environmentally sustainable supply", typically a much smaller quantity, but a more realistic measure of available supply. Supply must correspond to a specific spatial and temporal pattern of demand, and limits supply to a quantity that can be relied upon without adverse effect on future use or the environment.

For **surface water**, four factors must be incorporated sufficiently in a representation of water supply:

- **Accessibility.** First, the ability to convey water to a demand center (for example, an irrigation district or city) where and when it is needed, defines what can be considered "supply." For example, the definition would account for the fact that an existing reservoir that captures water in the winter can only deliver a portion of that water to a summer planting season in a non-adjacent irrigation district. In other words, the acceptable minimal standard of water quality is also important in defining water supply that is "accessible". If water can be delivered by infrastructure, but is impaired to a degree that it cannot be used for agriculture, it would not considered "accessible" under our definition.

- **Environmental requirements.** Second, a certain quantity of water required for ecosystem maintenance must be reserved. Many environmental requirements are met by inaccessible flows (such as seasonal flood waters), which should be protected but which do not compete with human access. But in basins with a significant degree of water infrastructure and demand, environmental flows may also need to be met by water that is already controlled and accessible for human use. Though this could be considered a demand, we represent these requirements as quantity that should constrain supply. We rely on expert judgment as to what these incremental environmental requirements should be on top of uncontrolled flows for each basin.

- **Reliability.** Third, water supply needs to be available on a reliable basis. Renewable surface water availability varies year by year depending on rainfall and other natural drivers. For example, reservoir infrastructure, which converts renewable water into water supply, may buffer this natural variability by providing a stock of water that is accessible during dry years. For our case studies, we define as "reliable" a supply amount which can be delivered 90 percent of the time, or 9 years out of 10.

- Finally, we need to consider any **other factors** that can alter the amount of accessible, reliable supply within a basin. These would include existing water transfers from adjacent basins and the use of nonconventional sources such as desalination.

For **groundwater**, the criteria for defining water supply are similar. The main issue is to define a supply that is accessible (for which pumping infrastructure exists and is sufficiently near a demand center, for example) but still reliable over the long term. We portray groundwater supply as the smaller of: (1) the renewable amount of annual groundwater recharge; or, (2) the installed groundwater pumping capacity within a basin. Some regions may choose to use fossil (non-renewable) groundwater reserves at least for a time. Such supply is excluded from this report, as it is not sustainable in the long term.

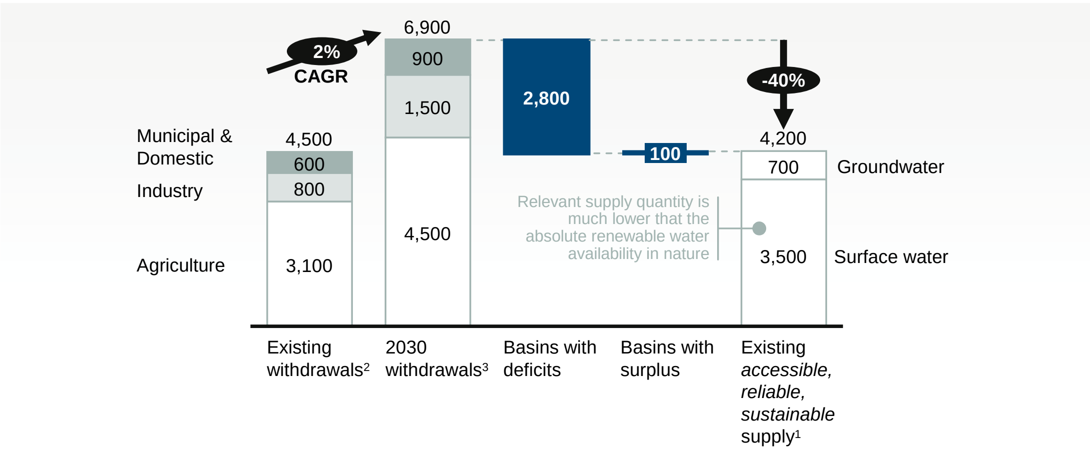
Our definition of accessible supply implies the ability of infrastructure to deliver water to demand centers and therefore implicitly includes the "return flows" from upstream withdrawals (such as an irrigation district, power generation plant, or even an urban area.)

Using this approach, we can build out a supply-demand gap for each of 154 basins or regions to 2030. Assuming current levels of water efficiency, unconstrained global water demand will grow at around 2 percent a year. This demand growth is driven chiefly by population and economic growth as reflected by increased agricultural and industrial production, and a wealth effect that entails greater water use by rising middle classes in emerging economies, whether for urban uses or for peri-urban agriculture. If we assume that this rate of growth continues, global water demand in 2030 will be close to double what it was in 2005—and 40 percent greater than the existing sustainable, reliable water supply (Exhibit 4). (Supply by this definition is a much smaller quantity than the absolute raw water available in nature, and is the amount that truly matters in sizing the water challenge.)

Exhibit 4

Aggregated global gap between existing accessible, reliable supply[1] and 2030 water withdrawals, assuming no efficiency gains

Billion m³, 154 basins/regions



1 Existing supply which can be provided at 90% reliability, based on historical hydrology and infrastructure investments scheduled through 2010; net of environmental requirements
2 Based on 2010 agricultural production analyses from IFPRI
3 Based on GDP, population projections and agricultural production projections from IFPRI; considers no water productivity gains between 2005-2030

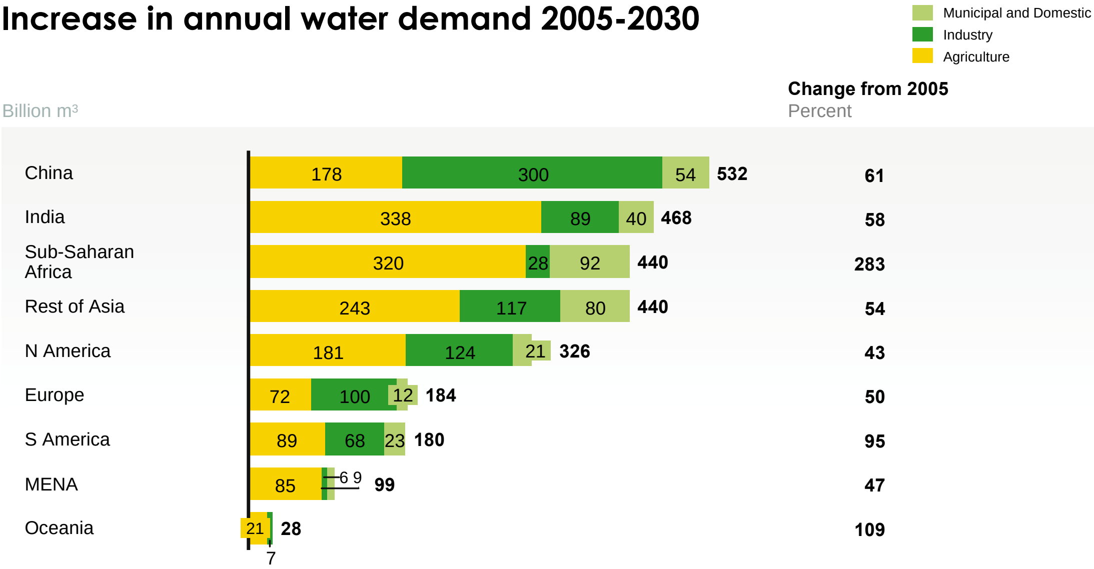
SOURCE: Water 2030 Global Water Supply and Demand model; agricultural production based on IFPRI IMPACT-WATER base case

This number by itself may not be surprising—after all, any growing demand, if unconstrained, will quickly leave behind supply that was designed to meet today's needs and the little that has been planned for the future. But when these numbers are coupled with the knowledge of how difficult it has been in the past to provide water to meet all of society's needs, it becomes clear why many observers believe that the water resource challenge is becoming a crisis. An analogy can be drawn with the energy sector, where the generating capacity of many rapidly developing countries is also struggling to keep up with economic growth. In that case, too, demand ultimately matches supply, but inadequacy of supply is reflected in the degree to which demand has to adjust to the availability of energy.

Agriculture—primarily in India and sub-Saharan Africa—will create the bulk of the additional demand to 2030 (Exhibit 5), although with significantly different underlying dynamics. In India, projected agricultural water withdrawals per capita are almost 800 m³/year in 2030, while in sub-Saharan Africa they are 323 m³/year on average, and in South Africa only 150 m³/year. Irrigated crops mainly responsible for the withdrawals include rice and wheat in India and maize, sorghum, and millet in Sub-Saharan Africa. The comparison between China and India is also instructive to understand the underlying drivers of demand. While both have large agricultural sectors, in India, agriculture will still be a significant driver of GDP in 2030 with a share of ~10 percent, while in China it will account for only 4 percent. In China, unlike in most other large economies, industrial demand for water dominates overall demand growth. In contrast, municipal and domestic demand will grow significantly across all emerging markets.

Exhibit 5

Increase in annual water demand 2005-2030



SOURCE: 2030 Water Resources Global Water Supply and Demand model; baseline agricultural production based on IFPRI IMPACT-WATER base case

"Business as usual" approaches will not mobilize the required investments

Calculating the size of the gap between projected water demand and existing supply is not by itself a full diagnosis of the water resource challenge in a country or basin. The calculation does not say anything about how hard it would be to close the gap, nor whether we would expect natural economic and social dynamics to find an optimal solution without intervention. A large projected gap for a particular country may have a very easy and accessible solution, adopted by the economy without undue difficulty or cost as water resources become scarcer compared to demand. On the other hand, a small projected gap for another country might be solved only by very difficult and expensive solutions, which we would not expect to be implemented without direct and purposeful investment. Chapter 3 discusses approaches to assessing the costs and potential of different types of solutions; in this chapter we focus on what history can tell us about our capacity to address such gaps.

As Chapter 1 discussed, investments in water provision and water efficiency have not historically scaled with GDP—because neither the scarcity cost of water nor the full cost of water management have been adequately expressed. As a result, instead of becoming more and more productive with an increasingly constrained resource, many economies are becoming less productive as there is little incentive to discourage waste. It is conceivable, therefore, that water resource management will continue in a "business as usual" mode, with historically slow rates of efficiency improvement along with suboptimal investment in supply—until a resource shock brings causes a painful adjustment to reality. Indeed, if past experience is anything to go by, the future may see an unplanned, inadequate growth of supply, where environmental flows, over-abstracted aquifers, and unmet demands bear the brunt of water resource mismanagement. Under these conditions it is legitimate to ask whether we would expect historical efficiency improvements to solve the gap by themselves, and whether closing the gap via additional supply—the traditional way of solving any water challenge—is a viable option.

Historic efficiency improvements would meet only a fraction of the projected gap

Agricultural yields in both rain-fed and irrigated areas grew at an annual rate of about 1 percent between 1990 and 2004[11], a major driver of overall water productivity improvements[12]. A similar rate of improvement occurred in industry. Were agriculture and industry to sustain this rate of improvement through 2030, it would address only 20 percent of the supply-demand gap, leaving a large deficit to be filled. Similarly, a business-as-usual supply build-out, assuming constraints in infrastructure rather than in the raw resource, will address only a further 20 percent of the gap (Exhibit 6). Even today, a gap between water demand and supply exists when some amount of supply that is currently "borrowed" from environmental requirements is excluded, or when supply is considered from the perspective of *reliable* rather than *average* availability.

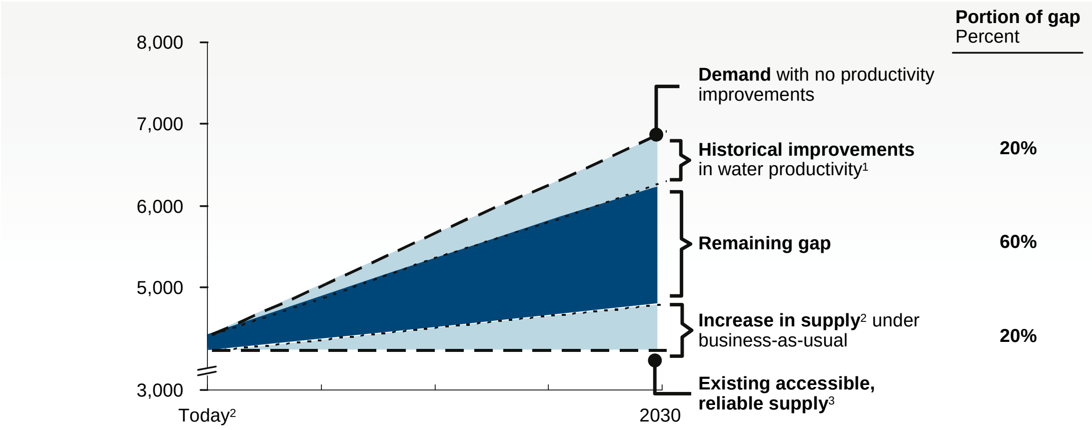
11 Historical FAO yield data for 12 different crop groups,
12 As water productivity includes the aggregate effect of yields (tons/area) and water application (water consumption/area), both rain-fed areas and in irrigated areas can reduce the total amount of water requirements for the same total amount of production. Additionally, trends in water application requirements per unit of yield are also taken into account for the projection of water productivity gains for each of 154 regions.

The impacts of global climate change on local water availability, although largely outside the scope of this study, could exacerbate the problem in many countries. While such impacts are still uncertain at the level of an individual river basin for the relatively short time horizon of 2030, the uncertainty itself places more urgency on addressing the status quo challenge.

Exhibit 6

Business-as-usual approaches will not meet demand for raw water

Billion m3



1 Based on historical agricultural yield growth rates from 1990-2004 from FAOSTAT, agricultural and industrial efficiency improvements from IFPRI
2 Total increased capture of raw water through infrastructure buildout, excluding unsustainable extraction
3 Supply shown at 90% reliability and includes infrastructure investments scheduled and funded through 2010. Current 90%-reliable supply does not meet average demand
SOURCE: 2030 Water Resources Group – Global Water Supply and Demand model; IFPRI; FAOSTAT

Traditional supply measures face a steep marginal cost

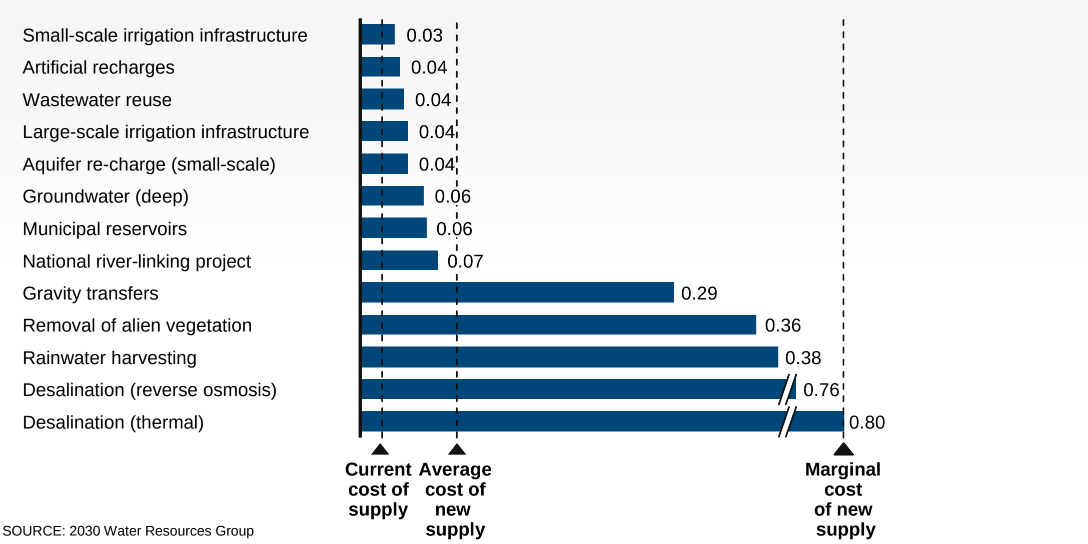
Closing the remaining gap through traditional supply measures would be extremely difficult—and costly. Such supply measures face a steep marginal cost curve, with the ceiling price set by expensive technologies such as desalination. As Exhibit 7 shows, many of the supply measures required to close the 2030 supply-demand gap in key basins studied would come at a cost between \$0.05-0.10/m^3—with the most costly measures could reach costs of \$0.50/m^3 or more.

Exhibit 7

Supply measures face a steep marginal cost curve

INDIA EXAMPLE

Cost of measure
$/m³



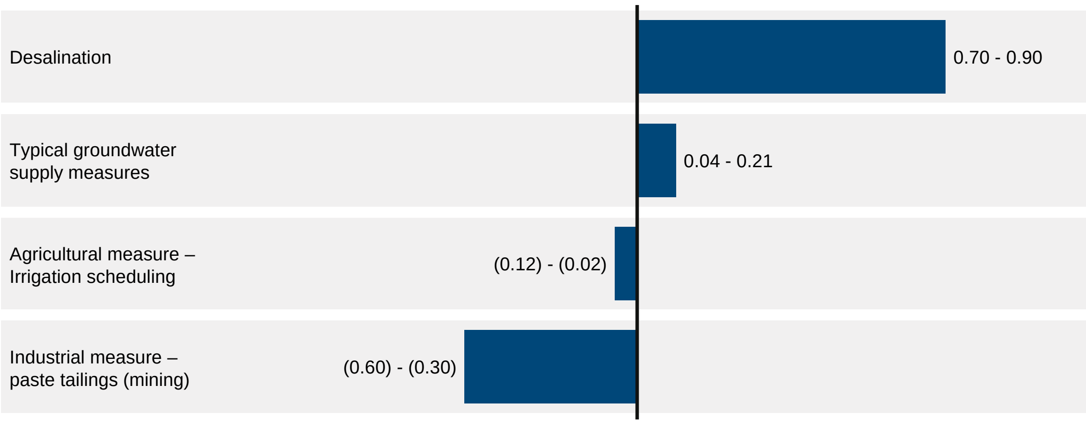
SOURCE: 2030 Water Resources Group

Without a new, balanced approach to close the gap, a supply-only solution implies additional investment in upstream water resource abstraction of $200 billion[13] *annually*, over and above current levels—five times the current annual global expenditure on this type of supply infrastructure. These costs could be even higher if additional costs for the treatment and sanitation are included. In the past, the scale of this investment need has meant that water requirements have not been met, particularly in developing countries. A comprehensive solution, as we will examine in Chapter 3, integrates both demand and supply options and has the potential to lower costs substantially by refocusing attention on demand measures which have significant net savings rather than costs (see Exhibit 8).

Exhibit 8

Representative demand- and supply-side measures

Cost of measure
$/m³



SOURCE: 2030 Water Resources Group

13 We have used an annualized supply cost of $0.07/m³ for these calculations.

The impacts of global trends at the local level

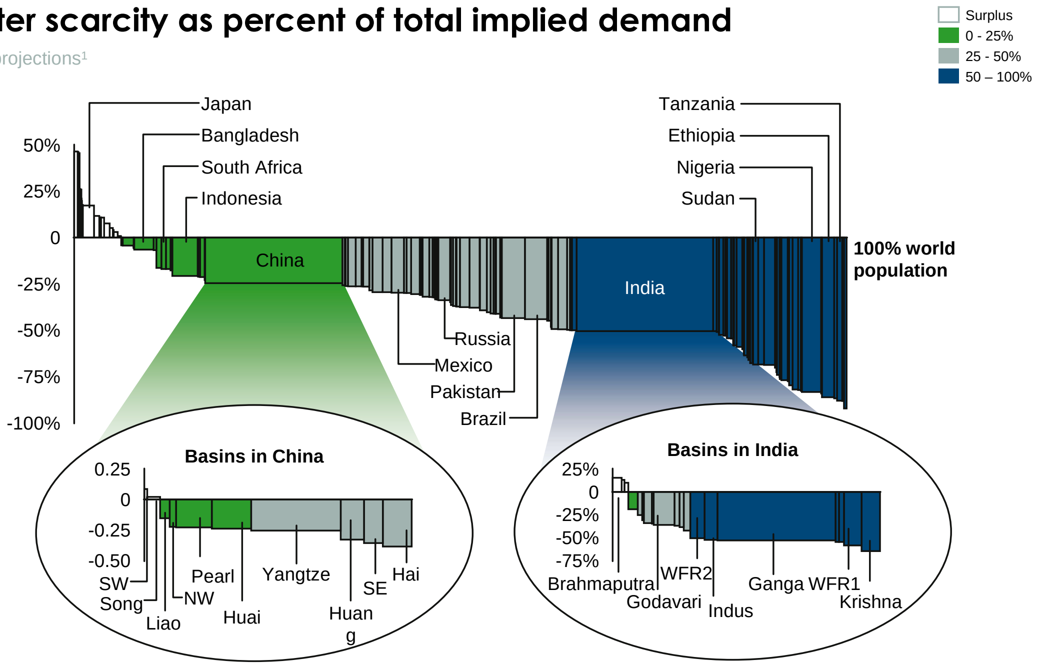
Calculating the gap between projected demand and current supply is particularly revealing at the national and local levels. The rate of annual global growth in the gap hides local peaks which may exceed 5 percent. The location of these peaks makes the challenge of the next two decades different from the past. Most of the world's people will live in basins with moderate to severe projected water deficits, and a third of the population—concentrated in sub-Saharan Africa and certain regions of India—will live in basins where this projected deficit is larger than 50 percent (Exhibit 9). Across the 154 regions analyzed in the global water supply/water demand model developed in this study, there is a clear correlation between projected population and economic growth and the size of the gap between projected demand and current supply, potentially exposing high-growth countries to particularly severe water scarcity issues in the decades ahead.

What Exhibit 9 shows is that there is no single characterization of the water gap. Countries in the same region may face dramatically different factors which lead to a gap. For example, Africa includes Tanzania, at the far right of the curve, and South Africa, which is at the left of the curve (albeit with a significant projected water gap). These examples also show that the gap does not tell the whole story: the real crisis happens not just when the gap is large, but also when it is hard to close, something that is very much dependent on the local situation.

Exhibit 9

Water scarcity as percent of total implied demand

2030 projections[1]



1 2030 projections, assuming technological innovation and infrastructure improvement investments are frozen at 2010 levels
SOURCE: 2030 Water Resources Global Supply and Demand model; based on IFPRI data

The global picture therefore is only helpful as context, and to make progress in solving the water challenge we need to take a more local view of the problem. Through this local lens we will be able to consider the impact that different drivers have on the problem of a growing gap between supply and unconstrained demand. Key themes—including water for food, the role of trade, and the role of water in development—can only be considered in the context of national and local conditions.

To understand these challenges in more depth, we undertook detailed case studies in four key countries and regions: India, China, the state of São Paulo in Brazil, and South Africa. Collectively these countries account for a large and growing share of the world's resources, output, and population (Exhibit 10). We also supplemented the detailed case studies with insights from other geographies to understand particular challenges (e.g. efficient water use in the arid countries of the Gulf Cooperation Council).

Exhibit 10

Case study countries as a percent of global total in 2005 and 2030

Brazil
South Africa
India
China

1 Conservative estimates. Some projections forecast China growing to over 24% of total 2030 GDP
2 Industry (or heavy industry) includes manufacturing, utilities, construction, mining
SOURCE: Global Insight; CIA World Factbook; 2030 Water Resources Group

The case study analysis profiled a range of water resource security themes, including the role of agriculture for food, fiber and biofuels as a key demand driver for water; the competition for scarce water; the nexus between water and energy; and the role of urbanization in water

resource management. While not exhaustive of all the concerns relevant for water management, these themes do capture a range of the most important challenges. Individually, the case studies focused on the following situations in each country:

- **India**—low agricultural water productivity and efficiency, combined with aging supply infrastructure, make severe supply-demand gaps likely in many basins with currently planned crop choices
- **China**—rapidly growing industrial and urban demand growth, along with an increasingly complex water-energy nexus, puts mounting pressure on supply
- **Brazil (São Paulo state)**—multi-sector activities drive quantity and quality issues in this highly urbanized, industrialized, and agriculturally active region, which accounts for 20 percent of Brazil's population and 35 percent of its GDP
- **South Africa**—fast-growing urban demand is outpacing supply, despite limits on agricultural irrigation use

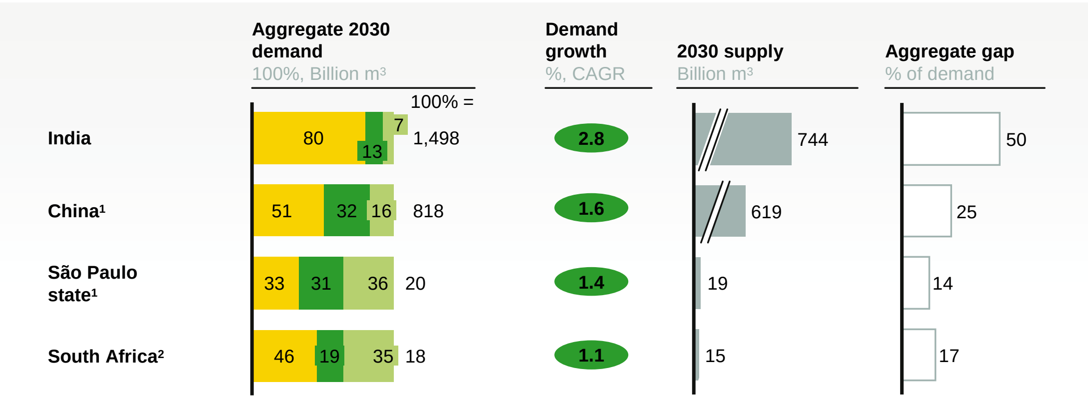
For each of the case study countries, the gap between projected 2030 demand and existing supply was calculated for a range of scenarios—a "base case" built on commonly accepted projections of economic and population growth. In some case studies, we also include scenarios to illustrate the separate impacts on water demand and supply of accelerated economic growth and severe climate change.

The gaps for each country—and for the basins within those countries—varied widely, as did the drivers of those gaps. For example, under the base case scenario, both South Africa and São Paulo face a 15 percent gap between projected demand and existing supply in 2030, with demand growth driven primarily by industrial and municipal and domestic use. India, however, faces an aggregate gap of 50 percent across all basins, driven by very rapid growth in agricultural and municipal and domestic demand (Exhibit 11).

Exhibit 11

Base-case demand, supply, corresponding and gaps for the regional case studies

Municipal and Domestic
Industry
Agriculture



1 Gap greater than demand-supply difference due to mismatch between supply and demand at basin level
2 South Africa agricultural demand includes a 3% contribution from afforestation
SOURCE: 2030 Water Resources Group

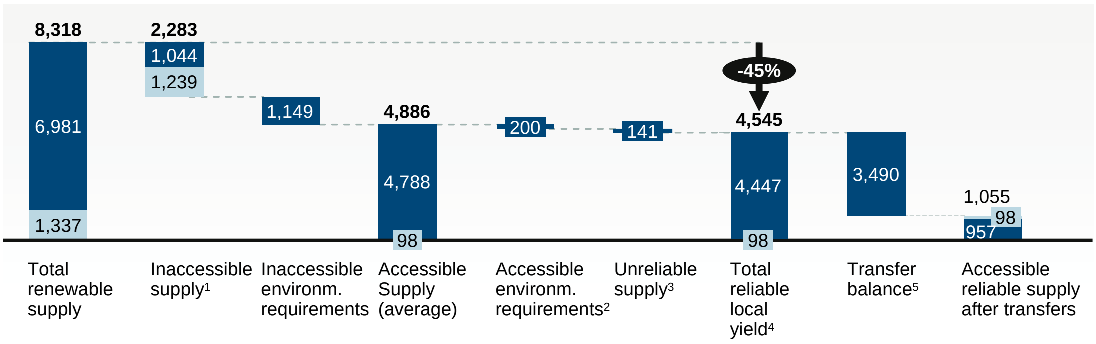
In each case study we have gone to the highest level of granularity afforded by the accessible data, always conducting analysis at the basin level and in many cases at the sub-basin level. We have calculated the amount of available, accessible, reliable resources, which is always a fraction of the total resources (Exhibit 12 provides an example), and projected the unconstrained demand to 2030 in order to calculate the gap between projected demand and current supply for each individual basin.

Exhibit 12

Quantification of the renewable water resource base and accessible, reliable, supply for a selected river basin

SOUTH AFRICA - UPPER ORANGE RIVER BASIN
Surface water
Groundwater

Million m³, 2005



1 Water lost because not captured by infrastructure or otherwise inaccessible, some of which can meet environmental needs
2 Additional water requirement unmet by inaccessible water resources required to sustain ecosystems further downstream
3 DWAF typically calculates reliability at 98%, but much of this unreliable component is included in the inaccessible supply
4 Includes return flows as part of the total surface water yield. Referred to as "local yield" by DWAF
5 The total difference left after taking into account all transfers in and out from WMAs. Some supply lost to evaporation in transfer
SOURCE: 2030 Water Resources Group

Two caveats are necessary on these demand projections. The first is that they are highly sensitive to assumptions, so the demand projections in this chapter should be seen as a "base case" projection based on common expectations of economic and social growth. The second is that, in the context of a report dealing with water gaps and how to solve them, the single biggest lever to resolve these gaps will often be to change demand drivers, for example by switching from a water-intensive crop to a less water-intensive alternative. A country's projected water demand will thus be closely tied to its economic development choices. We return to this point in Chapter 3 and again in Chapter 4, where we show how the tools developed in this study can be used to inform such decisions.

BOX 3

Different water for different purposes

All water is not the same. Water can be of different quality, spanning a continuous spectrum that goes from ultra-pure water, to potable water, to "gray water," to water that can only be used in agriculture, to water of impaired quality that is not fit for any use. Different types of water along the quality dimension are not necessarily fungible: water that is perfectly fit for agriculture may not be adequate for industrial use or human consumption and would require treatment in order to be used.

Similarly, reliability defines different types of water. Water that is available all the time is different from water that users can rely on only 90 percent of the time. Water that is available year-round is different from water that users can rely on only in a single season.

Both quality and reliability differentiate water, as they distinguish between the activities that can be supported, and therefore the value that water can have. Low-quality, low-reliability water cannot be used for human consumption in a city, for example, although it may be used as supplemental irrigation in lower-value crops. High-quality, high-reliability water, on the other hand, is very valuable.

In this study we have chosen to focus on the segment of water that needs to be shareable among all sectors as well as the environment: "raw" water of sufficient quality to be used in agriculture and as the basis for treatment in other uses, and that is above a standardized annual reliability of at least 90 percent. In other words, the bulk water resource that is shared between all sectors and the environment.

In principle, the same work could be done for different segments of water demand. In particular, while we have focused on the raw resource, the same methodology could be applied to high-quality, high-reliability water delivered by municipal systems. These "segments" of water products are linked and interdependent. For example, demand for low-value alfalfa could be separated from demand for high-value domestic water, and would affect the target "gap" for each demand segment.

Water for food: Agriculture in India

In our 2030 base case scenario, India faces a large gap between current supply and projected demand—amounting to 50 percent of demand or 754 billion m^3. This gap driven by a rapid increase in demand for water for agriculture, coupled with a limited supply infrastructure. One key uncertain factor that may affect the size of this gap is climate change. Its most direct effect is likely to be an accelerated melting of the Himalayan glaciers upon which several of India's river systems depend, particularly the western rivers such as the Indus, which relies on snowmelt for approximately 45 percent of its flow. Though in the immediate future increased snowmelt should actually *increase* flows of these rivers, in the long run the impact is very likely be a *decrease* of between 30 to 50 percent[14].

Water demand

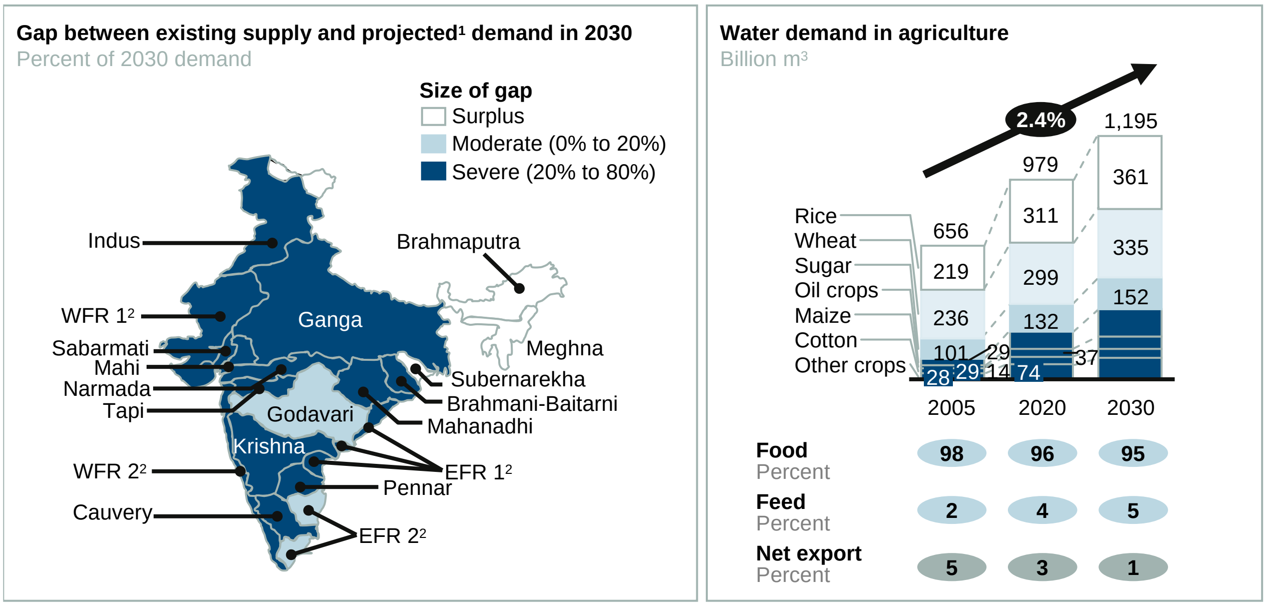
Though India is industrializing rapidly, producing sufficient food remains the country's primary water challenge (although reducing the impact of destructive floods is also a critical concern in some regions). Population is assumed to be growing at 1.0 percent per annum, and GDP at 6.8 percent per annum between 2005-2030. During the same period, the share of agriculture in GDP decreases from 19 percent to 10 percent. But because the vast majority (more than 95 percent) of agricultural production is and will continue to be for domestic consumption, the growing population coupled with an average increase in wealth mean that increasing caloric intake of the national population will be one of the key trends underlying the water resource challenge. Overall, the unconstrained demand implied by this production growth, driven by the rapid increase in demand for food and feed crops, particularly rice and wheat, would mean that in 2030 agriculture will account for almost 1,200 billion m^3 or 80 percent of total water demand—almost double agriculture's water demand in 2005. Projected municipal and domestic water demand will also double by 2030, to 108 billion m^3 (7 percent of total demand), while projected demand

14 See, for example, Rees, G. H. and Collins, D. N., *An Assessment of the Impacts of Deglaciation on the Water Resources of the Himalaya*, Wallingford: Centre for Ecology and Hydrology, 2004

from industry will quadruple to 196 billion m³ (13 percent), pushing overall demand growth close to 3 percent per annum. This demand, weighed against today's reliable, accessible supply, would create severe projected deficits for most of India's river basins (Exhibit 13).

Exhibit 13

India – Water supply and demand gap



1 The unconstrained projection of water requirements under a static policy regime and at existing levels of productivity and efficiency
2 WFR = western-flowing coastal rivers; EFR = eastern-flowing coastal rivers
SOURCE: 2030 Water Resources Group

In the base case projection for India, of the projected 685 million metric tons of food production in 2030, 175 million tons are expected to be rain-fed, leaving 510 million tons of irrigated production. Underlying these numbers is the assumption that existing rain-fed lands would reduce slightly in extent given some conversion to irrigated lands, and that additional crop demand will primarily come from additional irrigated lands. For irrigated production in 2030, projected demand from rice will be 361 billion m³ or 30 percent of irrigation demand, followed by wheat (335 billion m³) sugarcane (152 billion m³) and oil crops (137 billion m³). These requirements of course do not necessarily reflect relative weight of yields due to different water intensity. For example, the existing requirement of rice for irrigation withdrawals is 3.7 billion m³ per million tons of production, while sugarcane requires 3.3 billion m³ per million tons of production. Withdrawals also differ between basins. For example, in the Ganga, sugarcane requires 3.7 billion m³ per million tons of production, in the Krishna basin only 3.0 billion m³. These differences in the water requirements also reflect the current mix of irrigation technologies applied to each crop and in each basin, the source of irrigation (surface water or groundwater), and differences in the local climate.

Water supply

At 2,518 billion m³, the total water resource base for India, including surface and groundwater, is substantial but highly variable: during the monsoon season 50 percent of annual precipitation falls in less than one month and 90 percent of river flows occur in only 4 months of the year[15]. The ability of the current infrastructure to buffer that variability is low, making it difficult for accessible, reliable supply to meet projected demand. With only 200 m³ of water storage capacity per person, compared to 2,200 m³ per person in China and some 6,000 m³ per person in the United States[16], India's accessible, reliable supply of water amounts to 744 billion m³, or 29 percent of its total water resource.

Data on groundwater availability is uncertain, but we estimate that out of a total 400 billion m³ of renewable groundwater, approximately 230 billion m³ are accessible reliably. Yet, the importance of groundwater for India cannot be underestimated. For example, groundwater has played a large role in the success of rapidly increasing grain yields in India's "Green Revolution," when higher-yielding seeds accompanied by fertilizer inputs multiplied the yields of India's agriculture. A key enabler of this yield increase was the use of both shallow and deep tubewells, allowing farmers more control of irrigation water.[17]

Water supply is not distributed uniformly across the subcontinent. The Ganga basin accounts for a large fraction of the accessible supply, with almost 311 million m³, split between groundwater (35 percent) and surface water (65 percent). This is also reflected in the individual basin gaps, with the Ganga having by far the largest demand, and thus representing the largest gap in 2030 at 350 million m³ or 53 percent of local demand, followed by the Indian tributaries of the Indus basin (106 million m³, or 52 percent of local demand) and the Krishna basin (90 million m³, or 64 percent of local demand). These three basins combined account for over 70 percent of the total gap in India.

Within the total supply, groundwater supply differs substantially by region as well. In some basins, such as the western rivers, the true renewable groundwater supply is much less than what is actually pumped, leading to massive overdraft, declining water tables and elevated pumping costs; while in basins such as the Eastern Ganges additional groundwater supply could be increased sustainably. In addition, the core challenge of availability of groundwater is compounded by rapidly deteriorating water quality in many areas of the country, which could reduce the quantities that can be considered accessible supply, even for agricultural purposes.

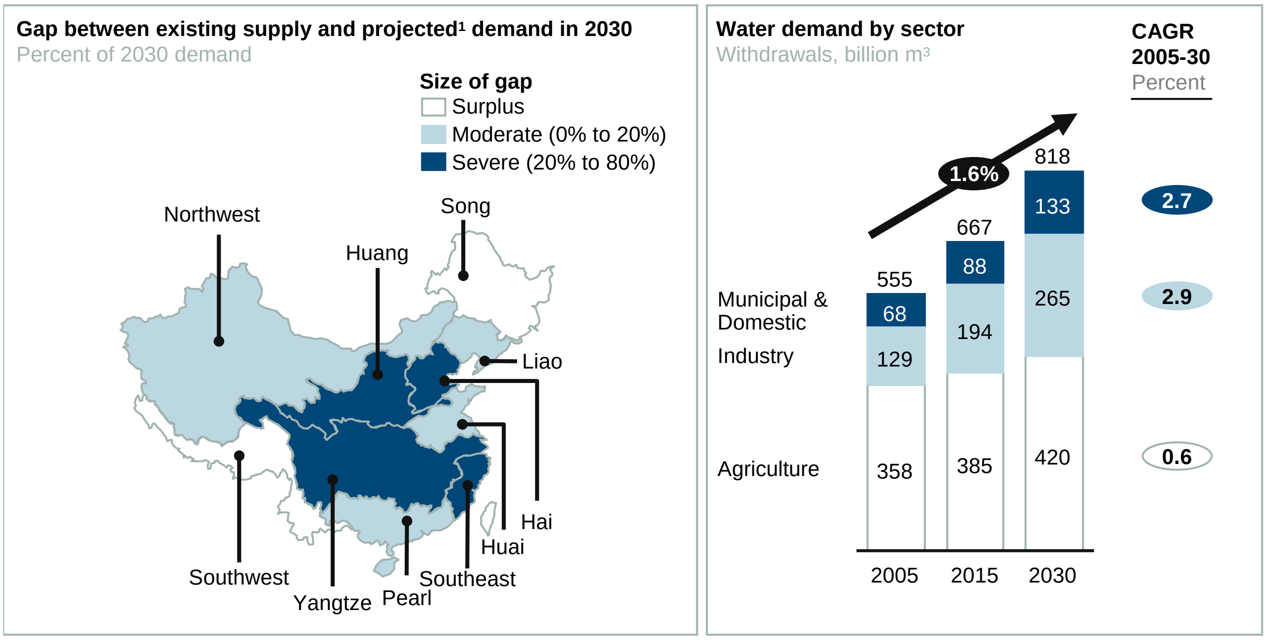
15 Briscoe, John and Malik, R.P.S. *India's Water Economy: Bracing for a Turbulent Future*, New Dehli: Oxford University Press, 2006, pg. 1
16 International Commission on Large Dams (ICOLD) database
17 Briscoe, John and Malik, R.P.S. *India's Water Economy: Bracing for a Turbulent Future*, New Delhi: Oxford University Press, 2006, pgs. 7, 10, 16

The water-energy nexus: China's fast-growing industrial and urban demands

China's fast-growing economy is driving rapid industrial growth and domestic urbanization. These two factors, coupled with a large agricultural sector with heavy water needs, together drive a gap of 201 billion m^3 between projected 2030 water demand and current supply under our base case scenario (Exhibit 14).

Exhibit 14

China – Water supply and demand gap



1 The unconstrained projection of water requirements under a static policy regime and at existing levels of productivity and efficiency
SOURCE: China Environment Situation Fact Book; China Agriculture Annual book; Study of China water resources strategy; China grain security planning; basin annual bulletin; press search; 2030 Water Resources Group

The nexus between water and energy is particularly critical in China for several reasons. The energy intensity of water provision is increasing rapidly as the transportation of water increases (particularly given the country's south-north water transfer project), and as energy-intensive water treatment becomes more widely used in the delivery of potable water for municipal and industrial systems. At the same time, the water resource is a key ingredient in China's power production base.

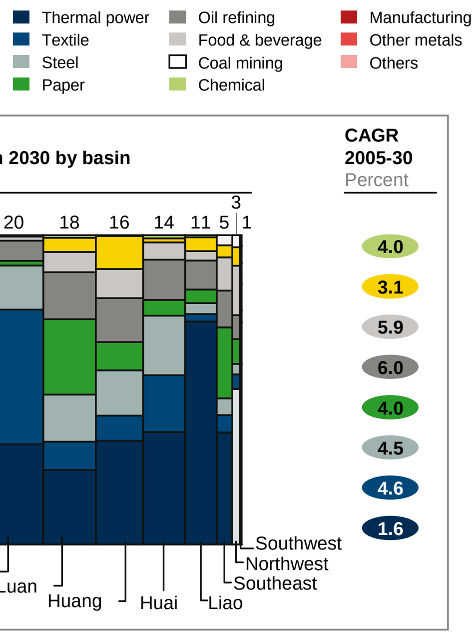
Water demand

Fast-growing demand could place strains on China's water resources. The greatest drivers of water demand growth are industrial and urban demand (Exhibit 14). That said, with China's self-sufficiency policy on food as a driver, agriculture will remain the largest water demand sector at 50 percent of total demand in 2030, or 420 billion m^3, even with a low growth rate of 0.6 percent. Irrigation provides about 80 percent of total agricultural output, with rice, vegetables and wheat accounting for 66 percent of agricultural water demand. The high demand for water in the agricultural sector is driven in part by the fact that flood irrigation is still the main approach adopted in China. Sprinkler and drip-irrigated farms make up less than 5 percent of the total for wheat, corn, vegetables, and oil crops.

The growth story, however, lies firmly in the industrial sector. If unconstrained by efficiencies, industrial water demand will grow at 3 percent annually from 129 billion m^3 in 2005 to 265 billion m^3 in 2030, with the highest growth in the next decade. Thermal power cooling accounts for 82 billion m^3 in 2030—by far the single largest source of industrial demand. The top eight industries account for 170 billion m^3, or 65 percent of industrial water withdrawals. Industry structure varies significantly across the 10 basins, leading to big differences in water withdrawal by industry and across basins (see Exhibit 15). The one constant is thermal power, which accounts for 31 percent of total industrial demand across basins in 2030.

Exhibit 15

China – Industrial water withdrawal demand in 2030



SOURCE: China Agriculture Annual book; Study of China water resources strategy; China grain security planning; basin annual bulletin; press search; 2030 Water Resources Group

Unconstrained urban water demand will grow at 3 percent annually to 133 billion m^3 in 2030, a fast pace for a country with less than 1 percent population growth. The emergence of a large middle class, from 4 percent of the population in 2005 to 56 percent in 2030, is the main driver of this growth, with household consumption accounting for two-thirds of the growth in demand. The middle-income urban populace will consume 74 billion m^3 in 2030.

Significant industrial and municipal wastewater pollution introduces additional challenges to China's water resources management in the area of water quality. The "quality-adjusted" supply-demand gap is therefore larger than the quantity-only gap, because some water is of such low quality that it can no longer be considered supply (Exhibit 16).

Currently, only 38 percent of municipal wastewater is treated, and often not to an acceptable standard. As sanitation coverage, urbanization, and population grow, the wastewater treatment gap will continue to swell, despite significant government-supported expansion plans. Industrial effluent treatment coverage is higher—91 percent—but still leads to discharge of metals, chemicals, and other toxins into the water supply. Annual growth of 3 to 7 percent in industrial water demand will mean similar growth in the need for treatment (whether water is to be discharged or recycled). Water salinity and other quality limitations render water unfit for agriculture in 21 percent of surface water resources nationally. In some basins, such as the Hai River Basin, the share of surface water classified as non-usable exceeds 50 percent.

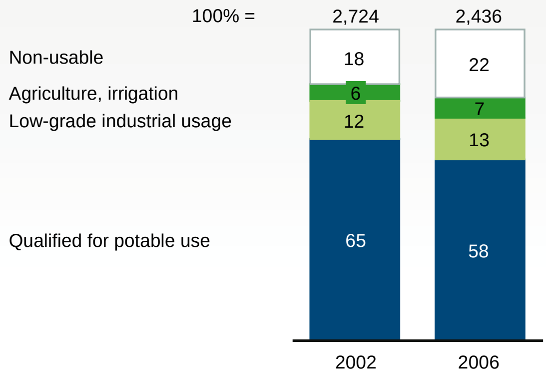
The biggest strains on both quantity and quality will be in China's most urban basins—the eastern Yangtze, the eastern Huang (Yellow), the Huai, and the Hai River basins. The concentration of China's quantity and quality challenges in these heavy urban and industrial basins aggravates the water-energy nexus challenge. Heavy water-using industries, like coal power, will face increasing water scarcity, and, in turn, will come under pressure to save water or lose out to renewable energy sources. At the same time, urban utilities will be looking for more energy-efficient ways to treat, transport, and even desalinate their water.

Exhibit 16

China – Rising water quality challenges

Surface water breakdown by quality level

Billion m³, percent



SOURCE: China annual environment bulletin; China annual water resources bulletin; China sustainable development strategy report 2007

Water supply

China's baseline supply is expected to reach 619 billion m³ by 2030 at an annual growth rate of 0.37 percent. Eight out of 10 basins will experience water shortages—with the largest percentage gap faced by the Hai Basin at 39 percent (23 billion m³) and the largest size gap faced by the Yangtze Basin at 70 billion m³ (25 percent). At 3,507 billion m³, China has a rich resource base of renewable water. Unfortunately, today only 20 percent, 563 billion m³, is both accessible and reliable.

In many ways, however, the supply story in China reflects its geographic disparity—basin-by-basin differences tell different stories. In the Huai Basin, infrastructure has captured almost 30 percent of the total 162 billion m^3. In other basins, such as the Hai, the total accessible water of 38 billion m^3 is even greater than total renewable supply 34 billion m^3. This is driven both by over-extraction of groundwater resources and by inter-basin transfers from the south (each approximately 3.7 billion m^3). In fact, the Hai Basin demonstrates the dichotomy in China's basin-level supply. It is divided between a water-rich south and a water-scarce north where most economic activity and population are located. In 2030, this divide will likely remain given current projections. The confirmed national cross-basin water transfer project can potentially provide some 11 billion m^3 of supply to water-scarce areas, including the Hai, Luan (4.3 billion m^3), Huai (4.1 billion m^3), and Huang (2.7 billion m^3) basins. Without these transfers, the accessible reliable supply in these regions would be reduced by approximately 8 percent. In 2030, the ambitious south-north water transfer project will potentially provide a total of 22 billion m^3 of water from the Yangtze Basin to the Huai-Hai-Huang Basins via three major transfers.

Quality versus quantity: Urban demands in the state of São Paulo, Brazil

In aggregate, Brazil has an abundant freshwater resource at over 5,645 billion m^3—more than double India's for a country with less than 20 percent of the population. Of this, however, only 47 billion m^3 (or less than 1 percent) is considered reliable water supply. We focused our case study on the Brazilian state of São Paulo, which accounts for 22 percent of the country's population, 34 percent of GDP, 60 percent of sugarcane ethanol production, and 70 percent of total industrial water consumption. This case study illustrates that fast-growing, multi-sector demand drives a gap of 2.6 billion m^3 between projected 2030 demand and current supply, even in an environment of abundant renewable water resources.

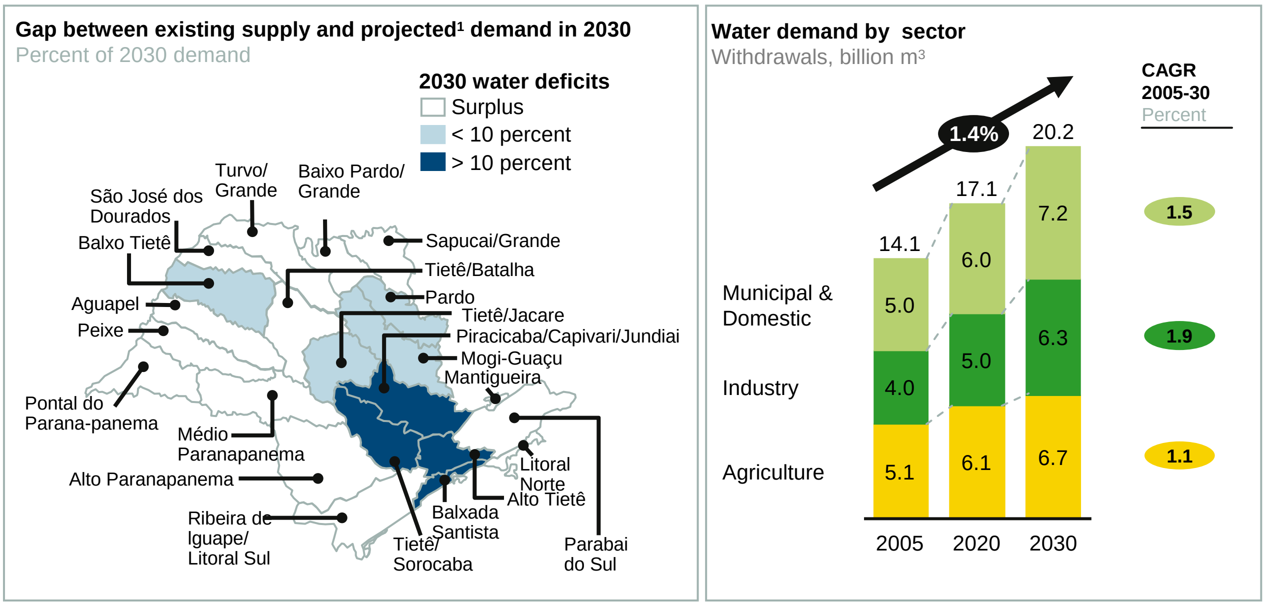
Water demand

Under our base case scenario, São Paulo's overall demand situation in 2030 will be divided evenly among agricultural, industrial, and municipal and domestic withdrawals at 6.7 billion m^3, 6.3 billion m^3, and 7.2 billion m^3, respectively. In agriculture, although sugarcane makes up 60 percent of the agricultural land in São Paulo, it accounts for less than 10 percent of irrigated demand (0.4 billion m^3). The top three irrigated crops—citrus, beans, and vegetables—are all high in value and will account for 4.5 billion m^3, or 70 percent of total irrigated demand. Unfortunately, São Paolo currently has among the least efficient usage of water for irrigation in the world at 14.5 million m^3 withdrawn per thousand irrigated hectares, almost three times the water usage of South Africa. Only 11 percent of irrigated land uses the most efficient technologies, which include drip and sprinkler irrigation.

Industrial demand will be growing even faster than agriculture, at 2 percent per annum through 2030. This will be driven in part by a 70 percent increase in water withdrawals in the petrochemical industry, from 0.6 billion m^3 to 1.0 billion m^3. Steel-related water withdrawals will nearly double from 272 million m^3 to 505 million m^3. The base case assumption indicates that ethanol-related water withdrawals will only grow at 1.4 percent. Total water withdrawals for domestic use will increase from 5.0 billion m³ in 2005 to 7.2 billion m³ by 2030, a 1.5 percent increase per year. The growth in demand will come primarily from the middle-income segment, whose annual water demand will increase from 1.7 billion m³ to 3.1 billion m³, as the middle-income share of the population swells from 29 percent today, to 37 percent in 2030. The middle-income segment uses almost twice as much water per capita as the urban low-income segment, and more than three times as much as the rural low-income segment. Due to this, 70 percent of the state municipal/domestic demand is driven by the macro-metropolitan region which includes São Paulo city, Santos, and Campinas.

Exhibit 17

Brazil (São Paulo State) – Water supply and demand gap



1 The unconstrained projection of water requirements under a static policy regime and at existing levels of productivity and efficiency
NOTE: Analysis focuses on macro-metropolitan area, and is not reflective of the entire state
SOURCE: 2030 Water Resources Group

Water supply

São Paulo state is rich in renewable water resources with over 98 billion m³/year fed by the Paraná Basin, more than the entire country of South Africa. But the topography and hydrology of the state make matching resources to use particularly challenging, yielding a reliable accessible supply of only 19 billion m³ (less than 20 percent of the total resource). In addition, environmental requirements constitute 25 percent of the total reliable surface water resource, reducing the amount available as water supply. In the base case, this supply has been fixed, given that there are no projects under construction. São Paulo has subdivided the main catchment basins into 22 distinct water management units, equivalent to sub-river basins[18] that exhibit dramatically

18 UGRHI – Undidade de gerenciamento de recursos hídricos (water resources management unit)

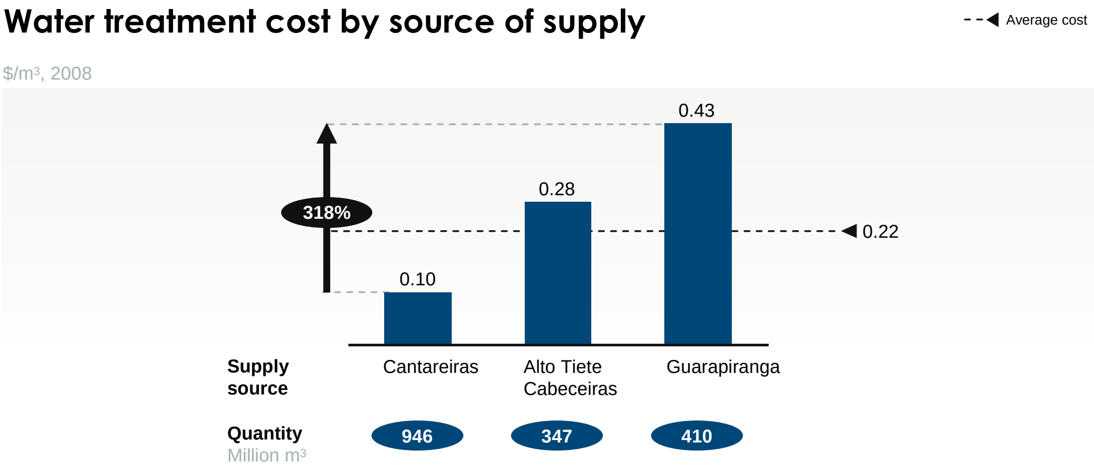
different yields. In the Alto Tietê water management unit, which largely overlaps with macro-metropolitan São Paulo, the access to renewable resources is higher (2.9 billion m^3 out of a resource base of 3.6 billion m^3, a yield of 80 percent) because of better infrastructure capacity due to high local demand. In Baixada Santista, on the other hand, the access to renewable resources is lower due to hydropower use and limited infrastructure capacity (0.9 billion m^3 out of a resource base of 6.6 billion m^3, or less than 15 percent).

Groundwater contributes only 7 percent of total accessible supply (1.3 billion m^3/year), but is the preferred source for 75 percent of municipalities and 35 percent of the population. As in India, groundwater is cheaper to abstract than surface supplies and more easily available in much of São Paulo state. The impact of this on river base flows and the environmental balance is unclear. Inter-basin transfers including those from the Amazon, which accounts for nearly 75 percent of the total 5,645 billion m^3 available in Brazil, are less than 1 billion m^3 for São Paulo state. Inter-basin transfers have been limited by a lack of water rights frameworks as much as from geographical challenges.

In the absence of improved sanitation and treatment, water of impaired quality will also reduce accessible supply in the key metropolitan basins. Water quality is already a major concern, and the growing costs of treatment in some polluted sub-basins give some indication of added costs to be expected above the costs of conventional supply, as shown in Exhibit 18. Water from the Guarapiranga has a cost of treatment of \$0.43 per m^3 to treat to usable quality, compared to only \$0.10 per m^3 for water coming from the Cantareira.

Exhibit 18

Water treatment cost by source of supply



SOURCE: SABESP; 2030 Water Resources Group

Scarce resources for development: Competition across sectors in South Africa

In our base case scenario, South Africa faces a gap between projected 2030 demand and current supply that amounts to 17 percent of demand, or 2.7 billion m^3. This scenario assumes that agricultural water demand is frozen by legislative action and incorporates typical growth projections for industrial activity. As with other case studies, our projections of water requirements do not assume efficiency improvement in any sectors.

The impacts of climate change might increase the size of this gap. As a plausible scenario to model these impacts—not a prediction—we calculated the impact of relatively small changes in rainfall and yield on existing supply sources (a decline of 3 percent compared to the base case for each) and a corresponding increase in irrigation requirements by 10 percent. Under these conditions, the gap in 2030 increases from 2.7 to 3.8 billion m^3. It is important to note that the water required to sustain environmental flows, about 20 percent of total water resources, may be at risk if other demands did not adjust under such a scenario.

Water demand

South Africa's agricultural, industrial, and urban demands account for 8.4 billion m^3, 1.5 billion m^3, and 3.5 billion m^3 respectively of the overall demand (Exhibit 19).

The basins that feed the largest cities—Johannesburg, Pretoria, Durban, and Cape Town—are expected to face severe gaps as municipal/domestic and industrial demand grows rapidly. In 2030, the Upper Vaal and Olifants, close to Johannesburg, will face gaps of 31 percent and 39 percent of demand, respectively. The Berg water management area—which includes Cape Town—will face a gap of 28 percent of demand. Unconstrained growth of household demand, at 1.8 percent annually, would outstrip population growth at 0.5 percent per year. Demand is driven by growth of the segments of the population which consume more water (lower-middle class and above), collectively increasing from 61 percent of the population in 2000 to 69 percent in 2009, and rising per-capita consumption of the low and middle-income segments, brought about by an expected broader use of showers, toilets, and increased landscaping in residential areas. Withdrawals for household use in 2030 are projected at 3.6 billion m^3, with the wealthiest quintile of the population accounting for half of these withdrawals.

Industrial demand is expected to grow from 1.5 billion m^3 to 3.3 billion m^3 in 2030. By then, power generation will account for 12 percent of total demand, mining for 18 percent, and manufacturing for the remaining 70 percent (up from ~50 percent in 2005).

Meeting the water demand for power generation is one of South Africa's water challenges. Up to 25 GW of additional power generation capacity is planned for 2025. South Africa is a country rich in coal, so for the coming decade additional capacity will come from dry-cooled, coal-fired power plants located where most of the coal beds are. The local water supply is typically insufficient for both coal mining and power generation, with water transfers likely to be required from other regions.

The mining sector uses water for processes and for dilution of acid drainage. Coal and gold alone accounted for 80 million m^3 and 90 million m^3 of demand respectively in 2005, but while gold will decline in the coming years, coal will become the primary water user in the mining sector at over 180 million m^3 in 2030. The amount of water needed for dilution of acid drainage is a particular concern. So far it has not exceeded the amount of water needed for other uses, so that no additional supply has been necessary for the sole purpose of dilution. While projections are very hard to make, it is possible that, as pollution increases, demand for dilution may exceed the amount currently required for other uses, implying the need for additional supply—likely transfers.

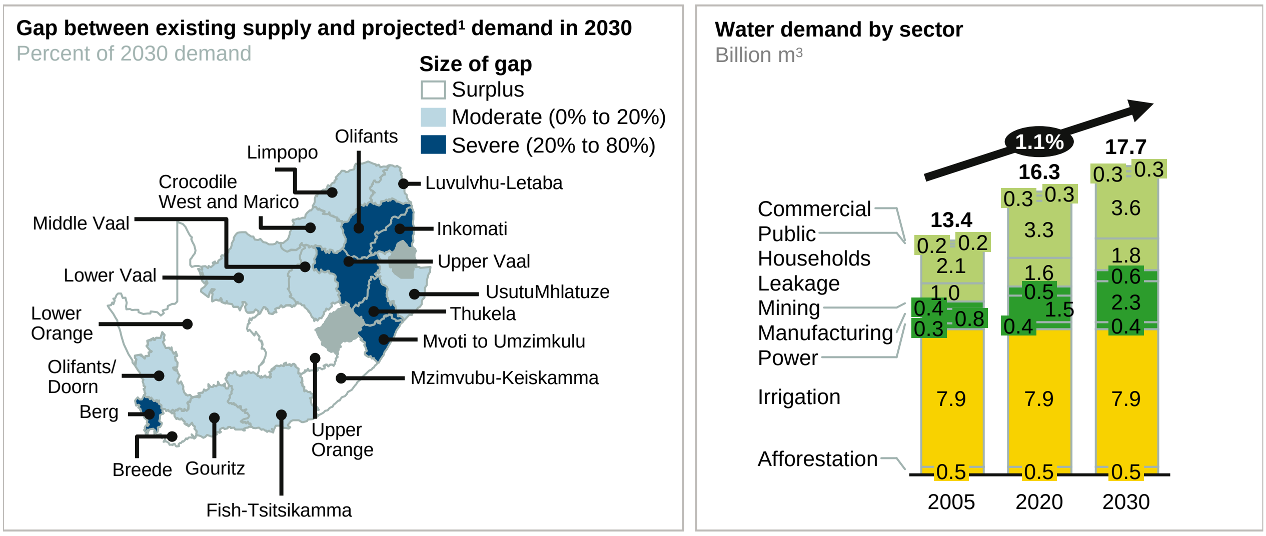
Agriculture is an important part of South Africa's economy. It contributes directly 3.7 percent to the country's GDP, but the agro-industrial sector as a whole contributes 15 percent of GDP. It also employs 7.5 percent of formal workers and constitutes 8 percent of total exports.

South Africa is 90 percent self-sufficient in food, and is a significant exporter of maize and fruit. South Africa relies on rain-fed land for 80 percent of its agricultural needs, and irrigates only 10 percent of its arable land. Irrigated agriculture is predominantly supplied by the Orange River, with also some irrigation in the Lower Vaal and coastal areas. Agricultural yield are high, comparable to those of Eastern European countries. Over 50 percent of the irrigated area is served through sprinklers and drip irrigation, particularly for horticulture and fruit cultivation, making it a relatively efficient water user.

Irrigation is unlikely to increase, as the national water authority has already capped agricultural allocations to current levels. Against these fixed withdrawals for water, though, demand for food and feed is expected to increase significantly over the coming decades, as the population's wealth and caloric intake increase. This will require significant increases in overall water efficiency and the productivity of rain-fed production (examined in Chapter 3), or a shift in trade.

Exhibit 19

South Africa – Water supply and demand gap



1 Frozen irrigation levels and limited ability to increase rainfed land will drive an increase in virtual water trade both between WMAs and internationally with trading partners

SOURCE: Water Research Commission; Department of Water Affairs and Forestry (DWAF); Statistics South Africa; 2030 Water Resource Group

Water supply

South Africa faces low levels of rainfall—about 50 percent of the world average—and receives around 10 percent of its run-off from neighboring Lesotho. It shares water courses with other countries in the southern African region. Rainfall is also highly seasonal with around 80 percent occurring within a span of five months. The rivers of South Africa are small (combined, their flow is less than 50 percent of the Zambezi) and shallow (resulting in a high rate of evaporation), so that with several inter-basin transfer schemes already in place, dam sites are becoming marginal.

In our base case, total renewable supply is just above 68 billion m³, of which approximately 19 billion m³ is renewable groundwater. Of this, only 15 billion m³ are currently accessible and reliable, including approximately 1.5 billion m³ from groundwater. In theory, an additional 25 percent of surface-reliable supply could be developed. Groundwater contributes only 15 percent of the total volume available, although over 300 towns and 65 percent of the rural population are entirely dependent on this resource for their water supply. The potential for additional groundwater is limited to approximately 2.3 billion m³, due to hard underground rock.

Water transfers among basins already form a critical part of South Africa's water supply. The Upper Orange receives over 4.4 billion m³ from Lesotho, almost 25 percent of South Africa's entire supply, much of which is then transferred downstream and to other basins.

Chapter 3
Toward solutions: An integrated economic approach to water resource management

> Approaches to close the supply-demand gap

> The water cost curve: A decision tool for closing the gap between projected demand and existing supply

> The cost curve in action: Toward solutions in the case study countries

Chapter 2 highlighted the worryingly large gap between projected water requirements in 2030 and today's water supply—and emphasized that "business-as-usual" water resource management is unlikely to close that gap without leaving significant demand unmet or causing serious harm to vulnerable populations and ecosystems.

This chapter, on the other hand, shows that a solution to this challenge is in principle possible, and that it need not be prohibitively expensive, provided the right institutional frameworks are put in place. It shows how a cost-effective mix of technical solutions, combining measures to increase water supply and to improve water productivity, could be assembled to close 100 percent of the base case water gap in all the countries studied. This chapter also points to a third, more challenging approach to closing the gap: eliciting changes in individual water-using economic activities, such as cropping patterns. Chapter 4 discusses the dialogue-rich stakeholder process required to consider and act on this approach, and to address the institutional, social and other non-economic issues that could stand in the way of implementing technically attractive water solutions.

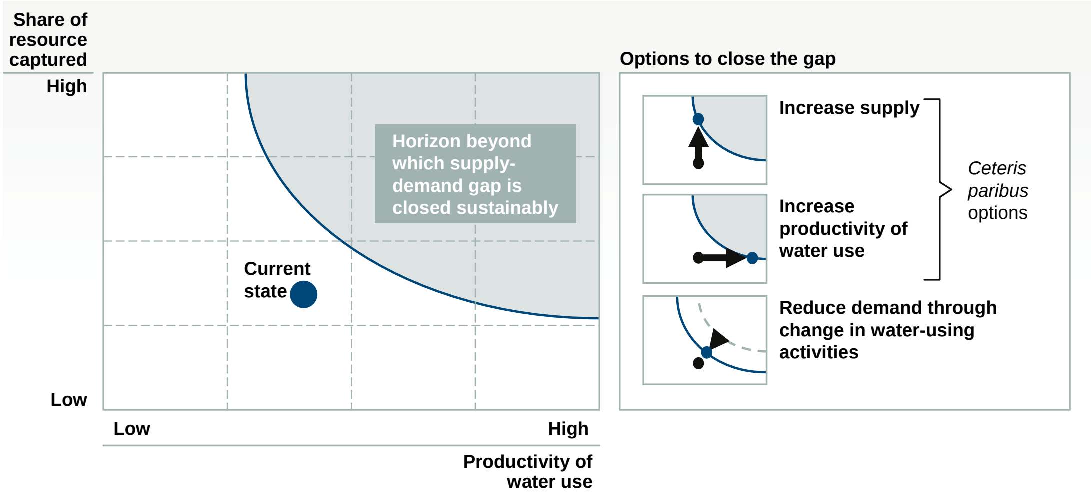
Approaches to close the supply-demand gap

A country's starting point on the path to water resource availability is determined by the current water productivity of different segments of the economy and the amount of water it is able to capture and deliver reliably. For most countries, that starting point is some way away from meeting a future "sustainable horizon" at which supply matches demand, through a combination of supply and demand productivity measures that allow the country to support its economic activities.

The challenge for the countries profiled in this report, and for many others, is to close the gap between projected future water demand and current supply in a way that meets their development objectives, is cost-effective, and protects people and ecosystems that are vulnerable to water scarcity. These countries' pathways to water resource security will entail some combination of three core ways of matching water supply and demand: expanding supply, increasing the productivity of existing water use, and reducing demand by shifting the economy towards less water-intensive activities (Exhibit 20).

Exhibit 20

Three options for closing the supply-demand gap



SOURCE: 2030 Water Resources Group

Consider the first option: simply increasing the amount of supply available for use. This is particularly relevant for those countries that have limited infrastructure but abundant water resources and therefore have the potential to convert that natural resource into available, accessible, and reliable water. In many countries, though, this has been the preferred option for a long time, with the result that this option has largely been exhausted (that is, all economic ways of supplying additional water have been used).

The second option for closing the water supply-demand gap is to increase the water productivity of existing activities across sectors of the economy. This entails either increasing the efficiency of water use (in other words, producing the same output with less water) or increasing production for the same water.

For policymakers and other stakeholders, these two approaches represent a "how" question: "How can the existing gap be solved technically—through supply levers, water productivity levers, or some combination of the two?"

The third option, though, departs from the *ceteris paribus* assumption and revolves around a "what" question: "What reductions in the water-using activities themselves can be encouraged?" Rather than simply deploying technical measures to close a water gap whose size has been predetermined by an existing economic development path, this approach entails shifting the country's economic activities toward less water-intensive ones. For example, a country could make a conscious policy choice of relying more heavily on agricultural imports in order to reduce withdrawals, thus effectively substituting the use of domestic water with water from elsewhere. (Because water issues have historically played little role in countries' economic decision-making, it is also entirely possible that planned or unplanned choices could increase, not reduce, the water-intensity of the economy, and with it the water gap.)

Different combinations of these three options will result in different costs and bring about different end-states for the country. Varying the country's economic outputs, the water intensity of its economy, and its reliance on supply-side infrastructure are all potential levers for achieving water security. The critical question is: what is the optimal mix?

We address this question in two stages in this report. As a starting point, we model cost-effective ways to close the 2030 supply-demand gap projected under the base case for each country studied. This is the focus of the remainder of this chapter. In this exercise, we consider only the first two approaches described above—measures to increase supply and improve water productivity—and assume no explicit policy decisions to influence the economic activities within the respective countries. The result of this analysis is encouraging: the optimal solutions identified will close 100 percent of the gap identified, at an annual capital cost (across all the case study countries) of some $19 billion in 2030.[19] When scaled to total global water demand, this implies a capital requirement of approximately $50 billion per annum for integrated supply and productivity solutions to close the projected water gap—just one-quarter of the roughly $200 billion per year that would be required for solutions built solely on an expansion of water supply.

In the real world, of course, decision-makers will need to consider and evaluate changes to a country's economic activities as part of the optimal mix of options to balance water demand and supply, so bringing the third approach discussed above into play. This approach is inherently different from identifying technical solutions to increase water supply or productivity: it requires trade-offs to be made across multiple economic and development objectives, whether shifting to different agricultural and cropping patterns, or choosing to rely more heavily on trade. Chapter 4, therefore, presents tools that decision-makers and stakeholders can use to compare the impact of different economic development choices on a country's water supply-demand balance. It also shows how such choices can affect the water gap, and the cost of filling it, in dramatic ways.

The water cost curve: A decision tool for closing the gap between projected demand and existing supply

The challenge in identifying the optimal mix of technical measures to close a given supply-demand gap—whether projected under base case assumptions or under a particular economic development scenario—lies in finding a way to compare different measures. To address this need, the 2030 Water Resources Group developed a "water-marginal cost curve" for each basin studied, as a tool to support decision-making. This cost curve provides a micro-economic analysis of the cost and potential of a range of different measures—spanning

19 Covering India, China, South Africa and Brazil – São Paulo

both supply expansion and productivity improvements—to close a specified gap (see Box 4: Assessing the cost of delivering water—the cost curve). Four types of technical measures are assessed on the cost curve, broadly covering increases in supply and different types of efficiency and productivity measures:

- **Agricultural productivity measures** which may improve both the efficiency of water use in irrigation and crop yields on both rain-fed and irrigated lands (see Box 5: "Accounting for blue water, measuring green water")
- **Industrial efficiency measures**
- **Domestic and municipal efficiency measures**
- **Supply measures** which increase "accessible, reliable, environmentally sustainable supply"[20] as defined in Chapter 2

The cost curve's use is limited to comparing measures' financial cost and technical potential to close the gap. It does not include or evaluate policies that would be used to enable, incentivize, or enforce the adoption of those measures such as pricing, standards, and behavioral changes. Rather, it provides information on what the cost would be of adopting a set of technical measures, which in turn can be used to inform policy design. Of course, cost is not the only basis on which water resource choices are made, but shedding light on the cost and technical potential of disparate measures allows these to be compared and evaluated in a common context. The cost curve, then, is not prescriptive: it does not represent what the plan for closing the supply-demand gap *ought* to be. Rather, it is a tool to help decision-makers understand and compare different options for closing the gap under a given demand scenario. We should emphasize also that the estimates generated by the cost curve are not explicit predictions, but approximate guides to decision-making.

20 According to Chapter 2 definitions (see Box 2), supply measures can provide "new" supply to demand centers but also increase accessibility or reliability of existing water provision (e.g. improving utility of major agricultural infrastructure or marginally increasing existing reservoirs to buffer more variability)

BOX 4

Assessing the cost of delivering water—the cost curve for incremental water availability

To close the gap between projected demand and existing supply for a particular basin, the possible solutions can be ordered on a cost curve (Exhibit 21).

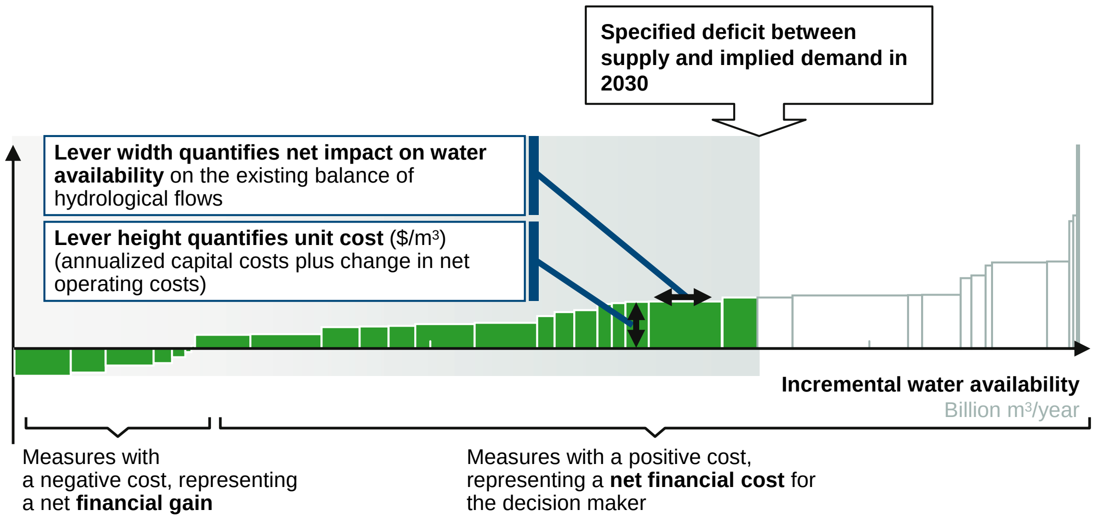
The cost curve's horizontal axis measures the amount of water made available by each measure to close the supply-demand gap. In applying the cost curve in the case study countries, we estimated the net impact of each measure on water availability, taking into account return flows (the water that, once withdrawn and used, flows back into the system). Some measures are more complicated than others to estimate—drip irrigation being a case in point. At a farm level, drip irrigation can have massive efficiency impacts, but at an aggregate level the impact could be different: by reducing return flows, this measure could actually reduce the supply available to others currently dependent on these flows and therefore diminish the true aggregate impact on closing the gap.

The vertical axis of the cost curve measures the cost per unit of water released by each measure in the year of the cost curve. This is the annualized capital cost, plus the net operating cost compared to business as usual. These are costs as measured from an integrated view—in other words the actual financial savings, rather than redistribution effects such as subsidies.

Exhibit 21

The water availability cost curve and specified supply-demand deficit

Net marginal cost in 2030
$/m³



SOURCE: 2030 Water Resources Group

The wider a measure on the horizontal axis, the larger its net impact on water availability to close the supply-demand gap. A measure's height on the vertical axis, on the other hand, indicates its financial cost—or savings—to the decision-maker.

BOX 5

Measuring "blue water", accounting for "green water"

It is worth relating this report's focus to the notion of "blue" versus "green" water, terms increasingly used in the communication of water resources concepts[21] to refer to where water is found in the hydrological cycle. "Blue water" describes water resources as they are typically envisioned—surface water in rivers and lakes, as well as groundwater aquifers, where they can be extracted and transported to other uses. "Green water", on the other hand, is the water from precipitation that naturally infiltrates into the soil and that the plant biosphere can use directly.

In this report, "blue water" is the currency in which supply and demand are measured. In calculating agriculture's demand for "blue water", however, we first subtract the amount of country crop production already met by "green water" (production from rain-fed lands).

When it comes to closing the "blue water" gap, overall improvement in the total crop production per unit of irrigation water is the goal—that is, "increasing crop per drop"[22]. Thus, we include agricultural measures on the cost curve which increase productivity in rain-fed agriculture (such as improved tillage and use of other inputs such as improved fertilizer and crop stress management (integrated pest management and other crop protection techniques). The resulting water productivity gains from "green water" essentially can offset "blue water" use elsewhere, and thus increase water availability to other water uses in a river basin.

The cost curve in action: Toward solutions in the case study countries

We applied the cost curve tool in each of the four countries and regions studied, at the national, basin, and in some cases sub-basin levels; in each case we assessed the potential of technical measures to close the 2030 supply-demand gap identified in the base case. The aggregate national cost curve developed for each of the country case studies revealed quite different local costs and impacts of otherwise similar measures, indicating that the standalone potential for technical measures to close a water supply-demand gap is unique for each country (Exhibit 22). For each of the country case studies, the cost curve pointed to the potential to construct a least-cost solution to close the base case gap. In particular:

- The cost curve for **India** demonstrates that a cost-effective solution would be built squarely on improving the water productivity of agriculture
- **China**'s solution would largely be built off managing the rapidly growing demand from industrial and urban uses.
- **São Paulo**'s solution would depend heavily on industrial as well as municipal and domestic efficiency
- **South Africa**'s least-cost solution would be built off a combination of supply and industrial efficiency levers

21 Falkenmark, M. and Rockström, J., "*The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management*", Journal Of Water Resources Planning And Management, 2006

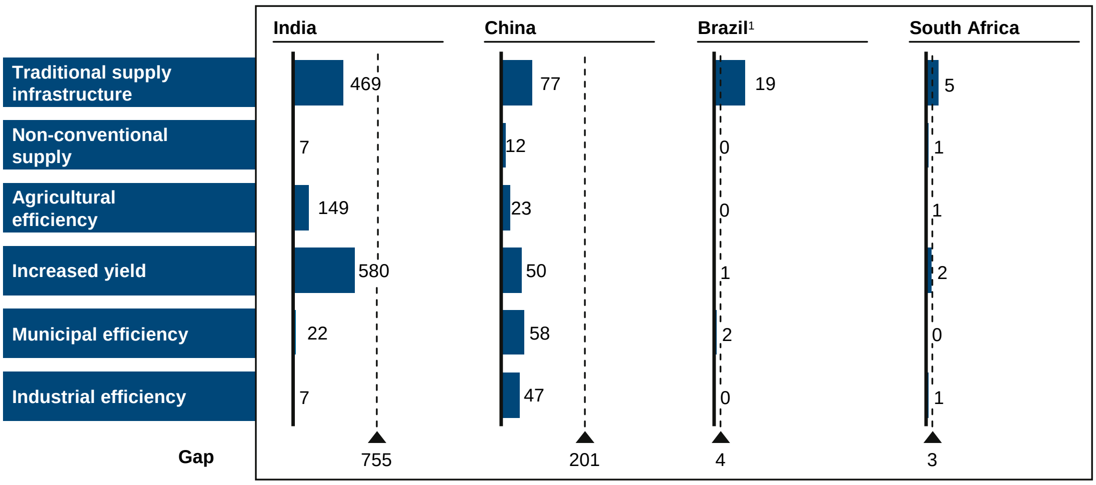
22 The Comprehensive Assessment for Water and Agriculture (IWMI, 2003) is a compilation of the potential water productivity gains in agriculture.

This section discusses the findings for each of these countries in turn.

Exhibit 22

Stand-alone technical potential of the measures by category

Water availability, Billion m³



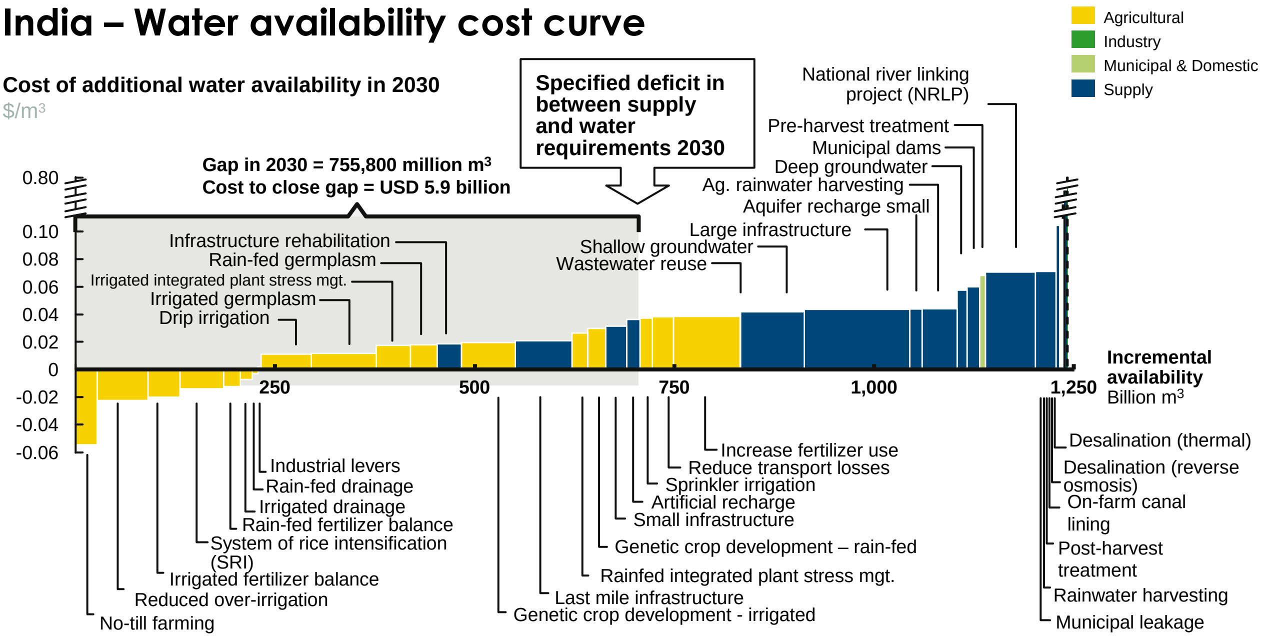
1 São Paulo state
SOURCE: 2030 Water Resources Group

The importance of agricultural productivity: A blue revolution in India

For decades India has been investing heavily in large-scale water infrastructure that has supported strong economic development in previously water-scarce regions. But, as previous chapters made clear, managing its water resources remains a key challenge for India in the years ahead.[23] We analyzed 37 measures to close India's projected base case supply-demand gap across 19 major catchment areas and basins. The resulting cost curve is shown in Exhibit 23.

Exhibit 23

India – Water availability cost curve



SOURCE: 2030 Water Resources Group

A number of important themes emerge from the analysis. First, by overlaying the projected supply and demand gap for India in 2030 on the cost curve, we see that the country has choices in how it closes the gap. The second realization is that if the cheapest options are selected, the overall annual expenditure in 2030 (including annualized capital and net operating expenditures) on managing the resource is $5.9 billion. This is not a large number for a country the size of India, although it is large compared to the amount of money spent every year on the water sector. Some estimates put India's 2007 total annual water expenditures (again capital and operating expenditures) at $12.3 billion, of which only $1.2 billion is devoted to managing the upstream resource.[24]

23 See, for example, Briscoe, John and Malik, R.P.S., India's Water Economy: Bracing for a Turbulent Future. New Delhi: Oxford University Press, 2006.
24 Global Water Intelligence – Water Markets India 2008

If we go from net expenditures to just capital requirements, then the annual investment capital needed for the least-cost solution in 2030 is $10.9 billion This number is higher than the net annual expenditure in 2030 given above, as some of the measures to close the supply-demand gap result in operational savings, bringing down net cost.

Probably the most important realization though, is that—as in previous decades—India's path to water resource security has much to gain from improving agriculture's water efficiency and productivity. Some 80 percent of the cheapest solutions to close the base case demand-supply gap lie in agriculture. That is not to say that agriculture is the only solution: the remaining 20 percent of solutions to close the gap lie in additional supply, albeit delivered mostly through the rehabilitation of existing infrastructure and last-mile canals. More traditional supply measures, such as the National River-Linking Project and desalination, are all on the more expensive, right-hand side of the cost curve. This of course does not mean that they should not be pursued—some traditional supply measures will double as flood control or provide critical hydropower needs, for example—but it does mean their selection will require financial trade-offs by decision-makers.

In effect, India's base case 2030 supply-demand gap could also be solved with agricultural measures only, but this would imply a net annual expenditure in 2030 of $8.4 billion. An infrastructure-only solution would be run up an annual expenditure in 2030 of $23 billion, four times that of the least-cost option, and would only meet 60 percent of the gap.

If 80 percent of the potential lies in agriculture, almost 80 percent of that lies in productivity levers—that is, measures that increase the yields of individual fields, offsetting the need for additional land and additional irrigation. This resource connection is important. To meet implied demand for food and feed in the country (only 4 percent of India's agricultural production is exported), some 31 million hectares of additional irrigated land would be necessary under water intensity frozen to today's levels. However, if existing rain-fed and irrigated land could be made more productive, additional land and therefore additional irrigation would be unnecessary, therefore reducing the amount of water required. A number of measures can be adopted to increase yields and therefore make land more productive, including no-till farming, improved drainage, optimized fertilizer use, utilization of best available germplasm or other seed development, and the application of crop stress management, the latter via both improved practices (such as integrated pest management) and innovative crop protection technologies. The biggest potential for such avoided land and water use comes from using improved germplasm—that is readily available today—on irrigated land. This lever alone could help close up to 11 percent of the gap. Improved germplasm on rain-fed land adds an additional 4 percent of the gap (improvements on rain-fed land on aggregate can avoid irrigation needs totaling 17 percent of the gap).

Other big agricultural opportunities are further investment in genetic crop development, improved irrigation control, and drip irrigation. Combined, they have the potential to contribute an additional 25 percent to closing the gap (as a productivity measure: drip irrigation increases the efficiency of fertilizer delivery and therefore increases the productivity of land and water).

If indeed the cost-effective potential to address the water challenge in India relies on productivity improvements, the solution cannot be divorced from national agricultural policy. It will require more than technological innovation. How will the measures described above be delivered to the hundreds of millions of subsistence farmers? In particular, there are basins where productivity gains could easily close the implied gap within the basin itself and go further, essentially off-setting irrigation demands in other basins. The Ganges River Basin, for example, could essentially play this role, becoming even more of a breadbasket than it currently is. In effect, this would mean that some of India's agricultural production would move from other basins to the Ganges River Basin.

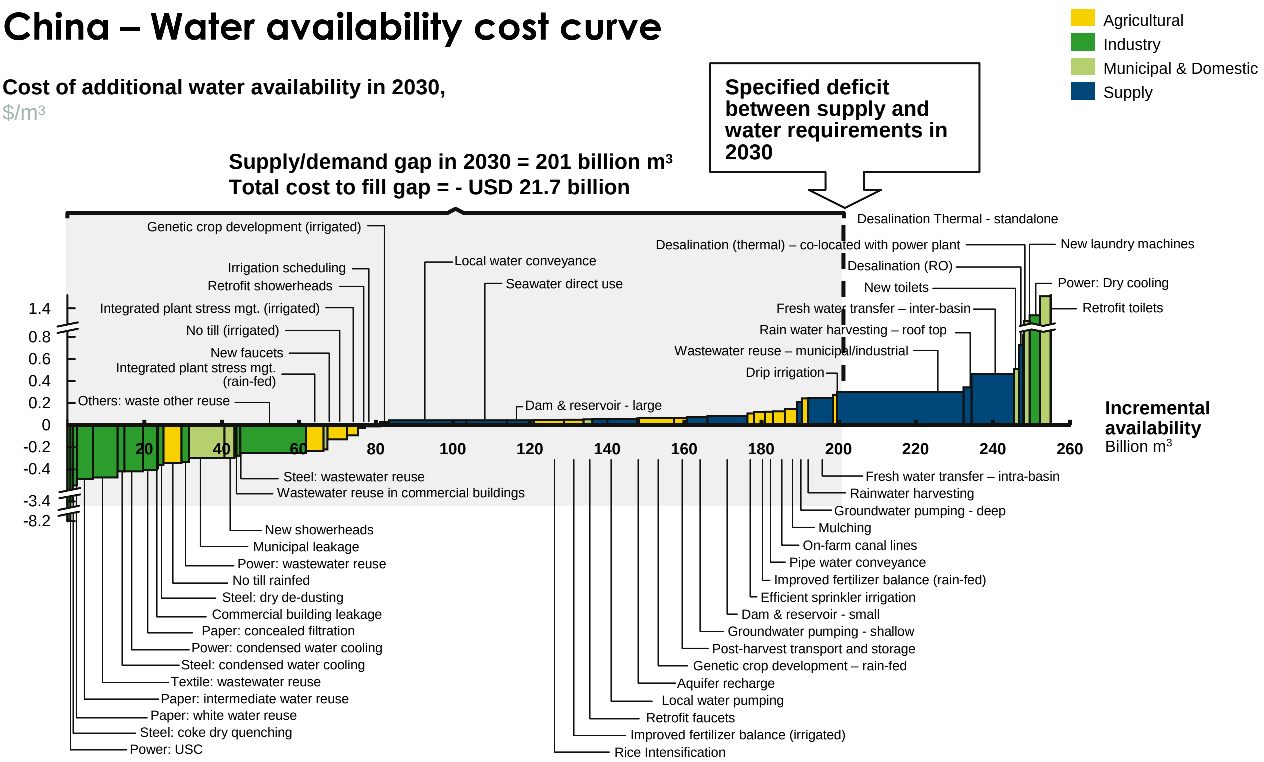
If, on the other hand, an assumption is made that each basin will need to solve its gap independently, the low-cost potential of the Ganges River Basin could not be applied to help close deficits in other regions. Instead, more expensive measures would have to be used in other basins that face a water deficit, resulting in an incremental annual cost of $1.4 billion. As we illustrate in Chapter 4, the fact base of technical costs can in turn inform meaningful, cross-sectoral dialogues around these tradeoffs.

China's industrial challenge

For China, we identified 55 levers to close the projected base case supply-demand gap of 201 billion m³ in the seven basins with a supply deficit in 2030. The resulting cost curve is shown in Exhibit 24.

Exhibit 24

China – Water availability cost curve



SOURCE: 2030 Water Resources Group

Although agriculture still makes up more than 50 percent of the total demand, industrial and urban water use are the fastest growing uses of water (at more than 3 percent per annum). China can curb this rapid growth in a cost-effective way by instituting aggressive, water-conscious "new build" programs that encourage the technical measures we have identified. If it does so, the cost to fill the gap in 2030 is negative (including annualized capital and net operating expenditures), implying net annual savings of approximately $21.7 billion. The incremental investment capital needed in 2030 to close the gap amounts to $7.8 billion annually.

As the cost curve shows, these savings are almost entirely achieved by adopting industrial efficiency measures. These have the potential to close a quarter of the gap and result in net savings of some $24 billion in 2030. They are distributed among the thermal power, wastewater reuse, pulp and paper, textile, and steel industries. Their savings potential comes mainly from the significant reduction in operational expenditures that they yield. Other factors besides economics need to be taken into consideration, as implementation can face strong barriers and incentives to adopt efficiency are low; thus companies would not invest in them by themselves. In these cases, China faces the tradeoff between diverting businesses' resources to water efficiency measures that may impede growth in the short term yet sustain and fuel growth in the longer term, versus supporting water use that is unsustainable in the long term, but allows for greater growth in the short term. Yet sustain and fuel growth in the longer term. Such opportunities arise where market growth in related sectors in turn helps develop new technologies and new local industries in water efficiency—for example where water treatment and reuse is growing to address increasing water pollution.

While China as a whole faces severe water scarcity problems rooted in rapid industrialization, solutions need to be explored at the basin, or sub-basin, level. In Daqing, for example, the solution involves curbing growing demand and leveraging alternative supply. In the Yangtze Basin, the solution will be built off capturing the region's plentiful rainfall. In Hai, although there is a significant south-north transfer in progress, the solution still involves significant efficiency measures.

China's solution to the water problem reflects its geographic expanse and extreme regional differences. Nowhere is this clearer than in supply. Supply levers can provide 37 percent of the solution in 2030 with an initial capital investment of around $2.3 billion per annum. Unlike more homogenous countries, different basins will use different levers. Surface water levers—those that can help capture a plentiful resource—will dominate in the Yangtze and Pearl basins where there are sufficient surface runoffs. Groundwater levers will be the main drivers of supply in the Northwest and Song Liao basins, although over-extraction in the Northwest is currently putting pressure on groundwater supplies. The most water-scarce regions, the Hai, Huang, and Huai Basins will require significant water transfers, wastewater reuse, and sea water usage to fill the demand gap.

Assuming accelerated economic growth beyond that modeled in the base case, the pressure on water resources rises further. The gap would increase by more than 25 percent, to a total of 255 billion m^3. The least-cost solution in this scenario would close the gap at an annual net expenditure of $4.8 billion in 2030.

In any scenario, though, meeting growing water demand fueled by rapid industrialization and urbanization will require a balanced solution of agricultural, supply, industrial, and municipal levers. This solution, however, must be considered alongside China's burgeoning energy demand. This "water-energy nexus" adds an important layer of complexity to China's future—as China (and other countries) adopt new energy sources, these are likely to require significant amounts of water. The energy sector is already the largest industrial water user in China and is increasingly exposed to the risk of water scarcity.

Opportunities exist for energy- and water-saving measures to go hand-in-hand. Implementing ultra super-critical processes in thermal power, boosts plant efficiency and reduces energy costs by $3.9 billion. At the same time, it lowers water-cooling needs, reducing water withdrawals and saving $8.20 per m^3. The cost savings per unit of actual consumption (the difference between withdrawals and return flows) is substantial, although water withdrawal savings also reduces the return flows which were previously available for other uses, thus decreasing the total impact on water demand. Similarly, coke dry-quenching leads to heat recovery in the form of steam in a waste-heat boiler—saving water and generating steam for electricity production, while driving considerable savings—$3.40 per m^3 of incremental water availability.

Balancing cost, energy production, carbon emissions, and water demand will be no easy task. In order to solve China's water and energy challenges conjointly, measures with a balanced performance should be prioritized. Strong penetration of overly water-intensive energy-savings measures and power plants (such as solar CSP, and coal-to-liquids), on the other hand, would need to be avoided—as would widespread adoption of overly energy-intensive water-savings measures such as desalination. Instead, growth in both sectors should focus on technologies that minimize the combined footprint. As a consequence, renewable technologies such as solar, wind, and hydropower that reduce consumptive water use may offer an important opportunity not only to the energy sector, but also to the sustainable management of water resources.

Quality and improved efficiency: São Paulo's macro-metropolitan area

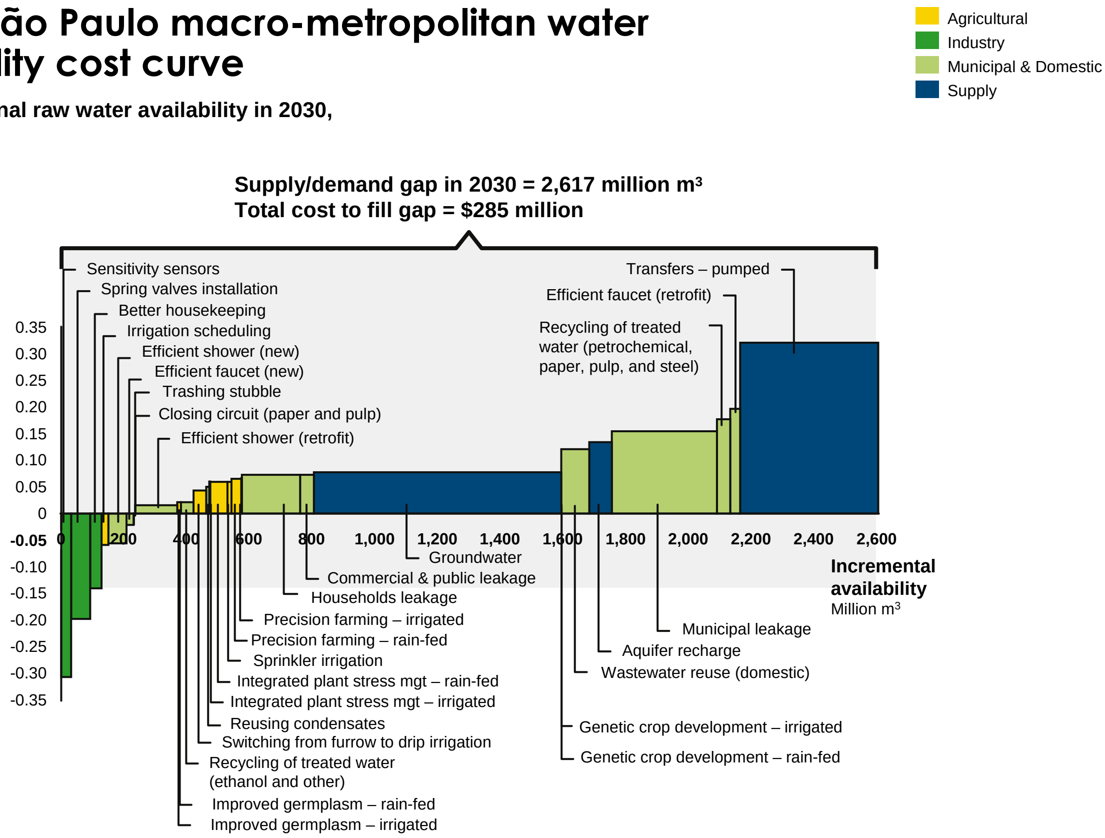
We analyzed 38 measures to close São Paulo's base case supply-demand gap, across the state's 22 water management areas (Exhibit 25). Closing the gap will require trade-offs to be resolved between industrial and urban water efficiency, new sources of supply, and water quality improvement. Solving the macro-metropolitan water availability challenge will mean focusing closely on the Alto Tietê Basin, which overlaps almost entirely with metropolitan São Paulo itself.

The least-cost solution to close the base case gap in São Paulo has a net annual expenditure in 2030 of $285 million (including annualized capital and net operating expenditures). A large part of the solution lies in efficiency improvements. A solution built on supply infrastructure alone would nearly double net expenditure in 2030 to $530 million per year. Excluding net operational expenditures, the annual investment capital outlay required for the least-cost solution by 2030 is $135 million per year, approximately half of total annual net expenditure. Of this amount, 71 percent is needed for additional supply infrastructure, and 13 percent for domestic and municipal measures. Agriculture and industry play a minor role at 7 and 3 percent, respectively.

Exhibit 25

Brazil – São Paulo macro-metropolitan water availability cost curve

Cost of additional raw water availability in 2030,
$/m³



SOURCE: 2030 Water Resources Group

Our analysis identified a wide range of cost-effective interventions to improve industrial and municipal water use efficiency. Since industries must treat their water twice—after abstraction and before discharge—saving on the quantity of water means saving on the treatment costs twice. Therefore, the industries in the Alto Tietê Basin can generate significant financial benefit—$0.10 to $0.30 per m³ saved—from reducing their water use via levers such as spring-valve installation and sensitivity sensors. The overall potential is small, however, totaling only $28 million in net annual savings by 2030.

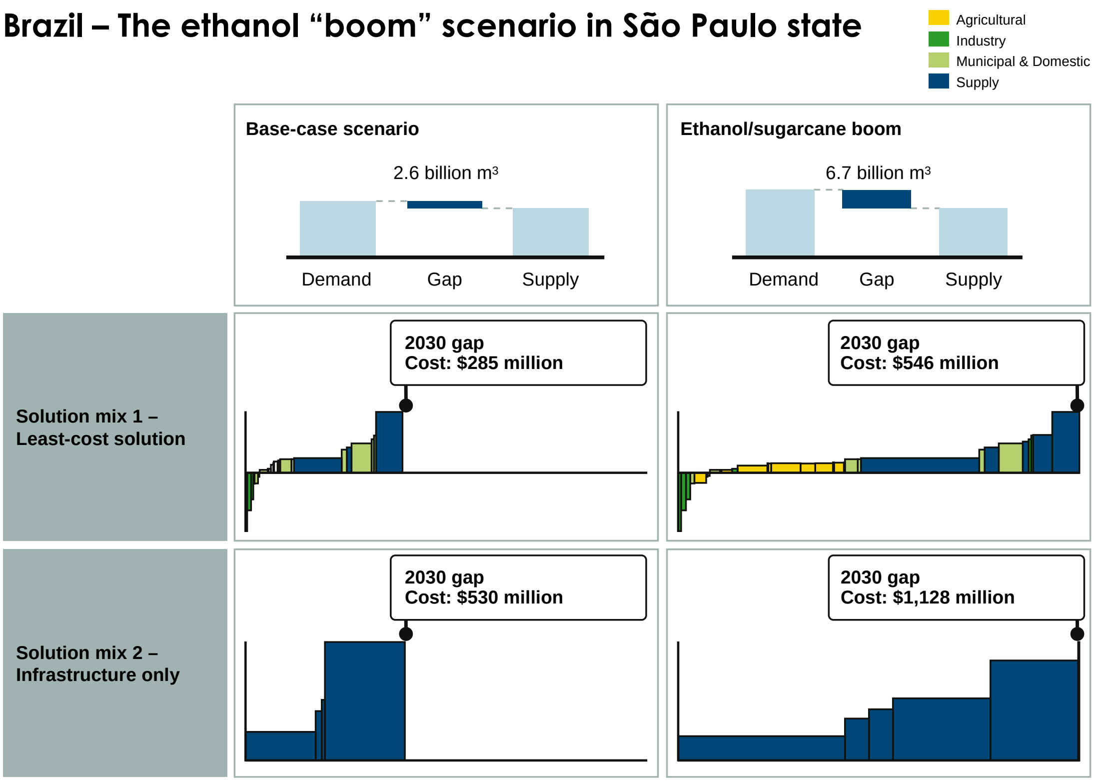
Urban water management offers a far larger opportunity than industrial water use, even if the available levers are less cost-effective. Efficient appliances deliver a range of opportunities, from net savings of $0.05 per m³ for new, water-efficient showerheads, to a net expenditure of $0.02 per m³ for replacing old showerheads with more efficient ones. Efficient toilets are already required by law in São Paulo, so are not considered as new levers. Household leakage reductions have a net expenditure of $0.02 per m³ and are difficult to capture. Commercial and public leakage reductions, however, have more potential, but cost no more than household leakage reductions.

The real opportunity in urban water management, however, lies within the control of the region's water utility, *Companhia de Saneamento Basico do Estado de São Paulo* (Sabesp). Sabesp has already made significant progress on leakage reduction, but a substantial opportunity remains for the use of new leak detection and repair technology. Utility leakage reduction can save nearly 300 million m³ at a cost of $0.15 per m³. Second, wastewater reuse for gray-water purposes (such as industrial processes and public works uses) offers roughly 80 million m³ in new water if Sabesp can meet its aspirations of growing reuse from less than 1 percent to 10 percent. In one success story, Sabesp has built a 6-kilometer pipeline to link treated discharge of its wastewater treatment plants with a petrochemical factory. These industrial and urban efficiency levers, along with wastewater reuse, offer attractive alternatives to costly inter-basin transfers.

A broader set of measures would need to be applied to close the gap if a spike in demand for ethanol as an alternative fuel is assumed. The resulting increase in sugarcane irrigation of an assumed 1.5 million hectares would prompt a nearly three-fold increase in the supply-demand gap, from 2.6 billion m³ to 6.7 billion m³ (Exhibit 26). The cost curve demonstrates that adopting agricultural efficiency levers would be critical in containing the costs of filling this widened gap. Under the ethanol boom scenario, the least-cost solution—one that mixes agricultural efficiency levers with other measures—would be $0.55 billion in annual net expenditures in 2030 (more than double the base case). If only supply-oriented levers are used, annual net expenditure in 2030 increases to more than four times the base-case, to $1.13 billion. As the water gap grows, the financial incentive to adopt the levers on the left-side of the cost-curve increases in lock step.

Exhibit 26

Brazil – The ethanol "boom" scenario in São Paulo state



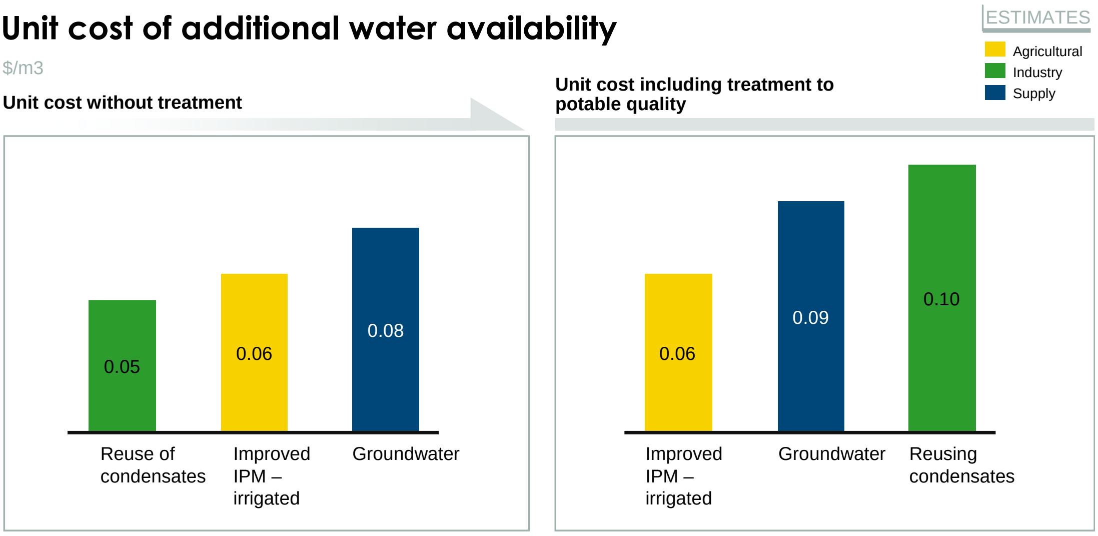
SOURCE: 2030 Water Resources Group

The Alto Tietê Basin imports 50 percent of its urban water supply and is considering further transfers despite having nearly 1.2 billion m³ of potential supply that flow down the Tietê River unused, in part because of high pollution levels. Therefore, any approach to solving the basin's water management challenges must consider the alternatives for resolving these quality issues, both for practical usage reasons and for environmental reasons. Because of these issues, it is reasonable that the metropolitan area has set a goal of treating nearly 100 percent of urban wastewater. But achieving this goal cost-effectively will be difficult. While resolving pollution issues—likely a 20-year process—São Paulo will need to understand the full cost of meeting its potable water needs while working with low-quality supplies. For example, the cost of treating water in the highly polluted Guarapiranga Reservoir is four times the cost of treating water transferred in from near the state border via the Cantareira water transfer system.

When considering the end-use purpose (mostly potable water in São Paulo), the logic of transfers becomes stronger due to lower treatment costs that offset the high pumping and capital buildout costs. The impact of treatment costs on different sources of raw water supply are shown in Exhibit 27. The resulting quality-adjusted cost curve points to a total annual net expenditure of $490 million for São Paulo state to address its water supply and demand gap in 2030, up from $285 million when only looking at raw water, as shown above.

Exhibit 27

Unit cost of additional water availability



SOURCE: 2030 Water Resources Group

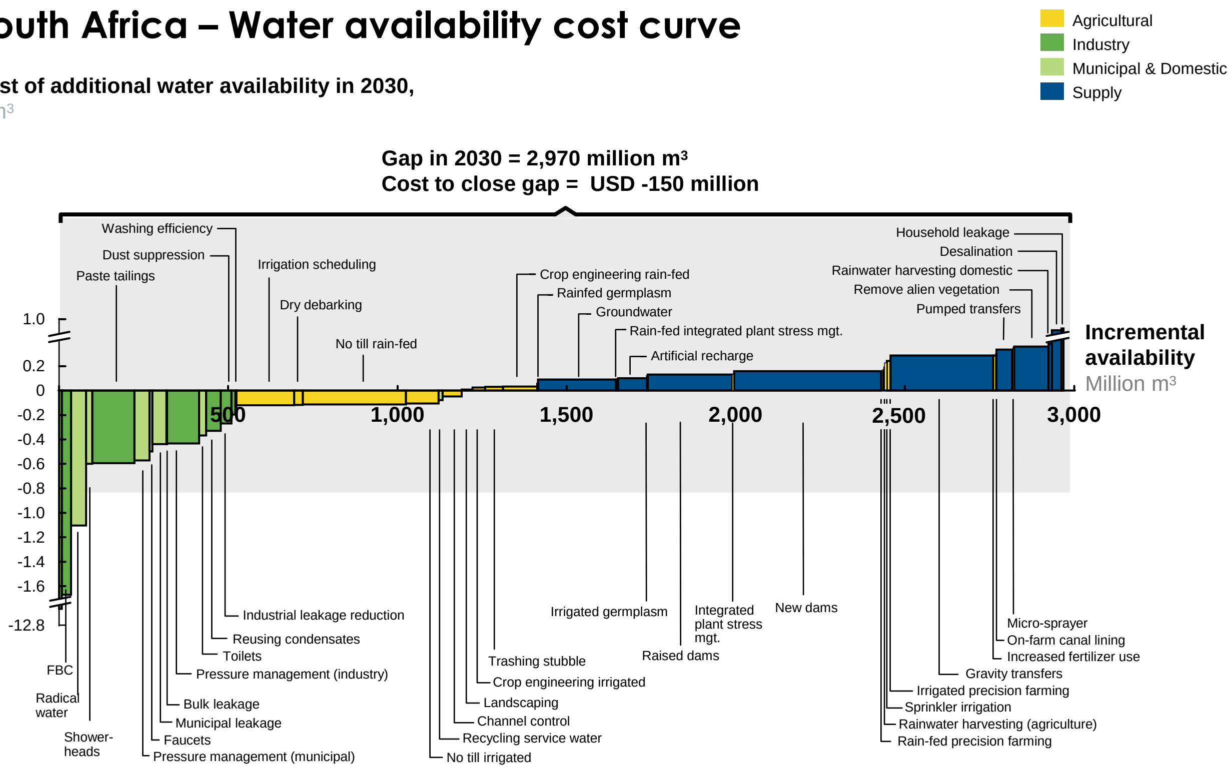
Industrial efficiency: Sources of value in South Africa

We analyzed 50 measures to close South Africa's base case supply-demand gap, across 19 water management areas, and 12 different crops. The resulting cost curve of a basin-level optimization is shown in Exhibit 28.

Exhibit 28

South Africa – Water availability cost curve

Cost of additional water availability in 2030,
$/m³



SOURCE: 2030 Water Resources Group

In aggregate, South Africa has a balanced solution for closing its demand-supply gap, with cost-effective measures available across supply (50 percent), agricultural efficiency and productivity improvements (30 percent), and industrial and domestic levers (20 percent). However, these solutions reflect the geographic differences within South Africa: at least seven water management areas are almost entirely dependent on agricultural improvements, while the economic centers of Johannesburg and Cape Town are dominated by industrial and domestic use.

The least-cost solution to close South Africa's 2030 base case gap points toward a significant savings potential from using water more productively. Implementing this solution would result in net savings of $150 million per year in 2030 (including annualized capital and net operating expenditures), because almost 50 percent of the levers we analyzed involve significant savings of other input costs, therefore effectively making at least half of the solution cost-negative. The top five measures in this sense are no-till rain-fed agriculture (10 percent of the gap), irrigation scheduling (6 percent), paste tailings in the mining industry (4 percent), no-till irrigated agriculture (3 percent), and improved pressure management in urban water supply systems to reduce losses (3 percent). The main driver of these cost savings is greater energy efficiency: these measures allow reductions of energy consumption of up to 20 percent. They also allow other input savings such as fertilizer, and often have lower maintenance than the equipment and processes they replace.

Excluding operational savings, the annual investment capital outlay required for South Africa's least-cost solution by 2030 is $365 million per year. Of this amount, 70 percent is needed for additional supply measures, 13 percent for measures each in industry and agriculture, and 4 percent in domestic and municipal uses.

In the case of industrial measures such as paste-thickening in mining and pulverized-bed combustion in power, substantial value can be captured from the pursuit of efficiency: up to $340 million in annual net savings (including annualized capital expenditures and net reductions of operational costs) are projected from the application of these industrial efficiency measures in 2030. In a basin like the Olifants, a rich source of coal and the location of many of South Africa's planned future mines and power stations, efficiency in industrial water demand plays an important role, providing 12 percent of the solution and saving $43 million per year in 2030.

The energy-water nexus is a challenge in this context, particularly in power generation. South Africa plans to double its power generation capacity by 2025 through a combination of mainly coal, gas, hydro, wind and nuclear power plants. Dry-cooling technology is expected to be implemented, which consumes 90 percent less water than wet-cooling technology. However, the technology is less efficient in cooling and produces higher emissions.

Beyond such industrial efficiency improvement opportunities, South Africa will also have to rely on additional supply sources. Demand centers are often geographically removed from additional supply. In the Olifants Basin, for example, additional local supply schemes contribute only 47 percent of the solution to close the gap. To supplement this supply, expensive inter-basin transfer schemes may be needed.

Chapter 4

Putting solutions into practice: New dialogue among stakeholders

> Building scenarios to model the impact of economic choices on water demand

> Tools for policymakers

> Pathways for the private sector

> The role of civil society

Chapter 3 showed that, for each of the four case study countries, technical solutions combining water supply and productivity measures are in principle available to close the base case gaps identified for 2030—and that those solutions need not be prohibitively expensive. These least-cost solutions, and the cost curves that model them, are a useful starting point in national or regional efforts to achieve long-term water resource security; they can form the basis for a "new dialogue" between public, private and civil society stakeholders that integrates water with broader economic development.

Such a dialogue will inevitably need to consider how to influence the size of the gap itself, by weighing options to elicit shifts in a country's economic activities that have an impact on water. The dialogue will seek to balance the objective of water resource security against other important economic and development objectives, and consciously make the often difficult trade-offs necessary for allocating limited water and financial resources. Further, it will address non-economic issues that could be obstacles to implementing water resource measures, such as institutional capacity and political feasibility. Finally, this dialogue will chart ways to mobilize the millions of water end-users who will need to change their behavior and spending decisions if an integrated solution is to be achieved.

This chapter shows how quantitative economic tools can be used to create the common fact base needed to underpin such a "new dialogue". First, it shows how scenarios can be constructed to compare the impact of different economic development choices on a country's water gap, and on the cost of closing it. Second, it shows how policymakers can modify the cost curve to evaluate both the implementation challenges of particular water resource solutions, and the adoption economics of those solutions from the point of view of end-users. Third, the chapter shows how private sector water users, investors and civil society organizations can themselves use the cost curve to identify the greatest opportunities to contribute to water resource security.

Building scenarios to model the impact of economic choices on water demand

In Chapter 2 we strived to quantify the problem of water scarcity at the country level and describe the natural implications of some of its key drivers—population, GDP growth, and agricultural output. We have also attempted to show, at the country and basin level, what a least-cost solution could be for such a base case of projected water demand, and how one could estimate the level of expenditure needed to fund it. But in reality, these least-cost solutions to close the base-case gap are no more than a starting point. Substantive progress towards a well-managed water resource will require decision-makers and stakeholders to revisit the drivers of the base-case gap itself, and in doing so consider options to reshape the water-intensity of the country's economy. Some of the drivers of country's projected water gap can be classed as endogenous—that is, subject to the direct influence of decision-makers and stakeholders. These endogenous drivers include future energy use, industrial growth, and agricultural production. Exogenous assumptions driving the gap, on the other hand, are those that countries may not directly influence in the short term—for example, climate change. In shaping a trajectory towards sustainable water management, a country would focus primarily on the endogenous drivers, conducting a high-level dialogue on broader economic questions such as:

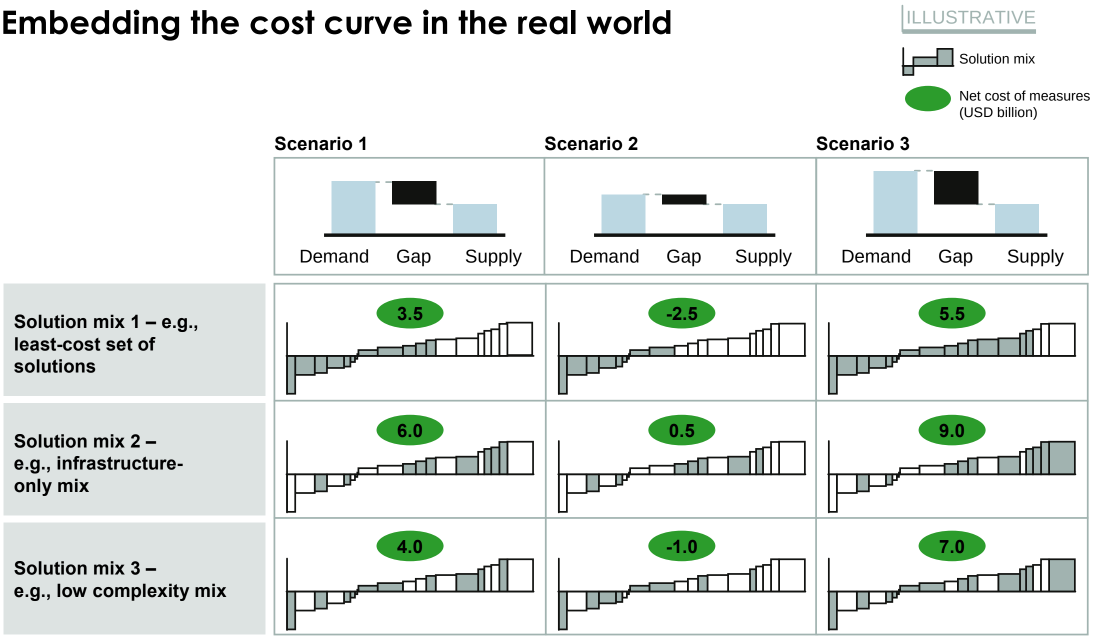
- Where agriculture is the primary user of water, what real options exist to influence the output of that sector (such as changing incentive or subsidy structures)?
- Are alternative energy plans available that would be consistent with the amount of water resources available? What is the trade-off between such plans and attempting to address the water challenge on a stand-alone basis?
- If water is really a limiting factor, could an economy shift to a less water-intensive manufacturing base, and if so, how?
- Are there enough water resources to support the demographics of the country, and if not, how can food and feed needs be ensured?

Practically, therefore, the first step in applying the cost curve and gap models in a stakeholder-driven process is to construct a set of demand scenarios that represent relevant economic and development choices facing the country. A shift towards renewable energy, for example, could dramatically change the need for water withdrawals from the power sector. A rural development policy based on increased access to fertilizers and subsidies may be contrasted with a shift towards high-value agricultural products with low-water intensity, or greater reliance on agricultural imports. Each of these scenarios generates a different water supply-demand gap, and for each gap a distinct cost curve can be developed as a menu of options to close the gap. As necessary, other gap scenarios based on exogenous factors can also be considered, to model the impact on water demand of climate change, changes in population growth, or even ranges of uncertainty in existing supply. In short, the demand scenarios seek to illustrate the implications for water of core beliefs about future supply and water-using economic activities.

Once these alternate gap scenarios have been constructed, the cost curve can be used to define different "solution mixes" for each scenario, from the menu of technical measures available, as illustrated in Exhibit 29.

Exhibit 29

Embedding the cost curve in the real world



SOURCE: 2030 Water Resources Group

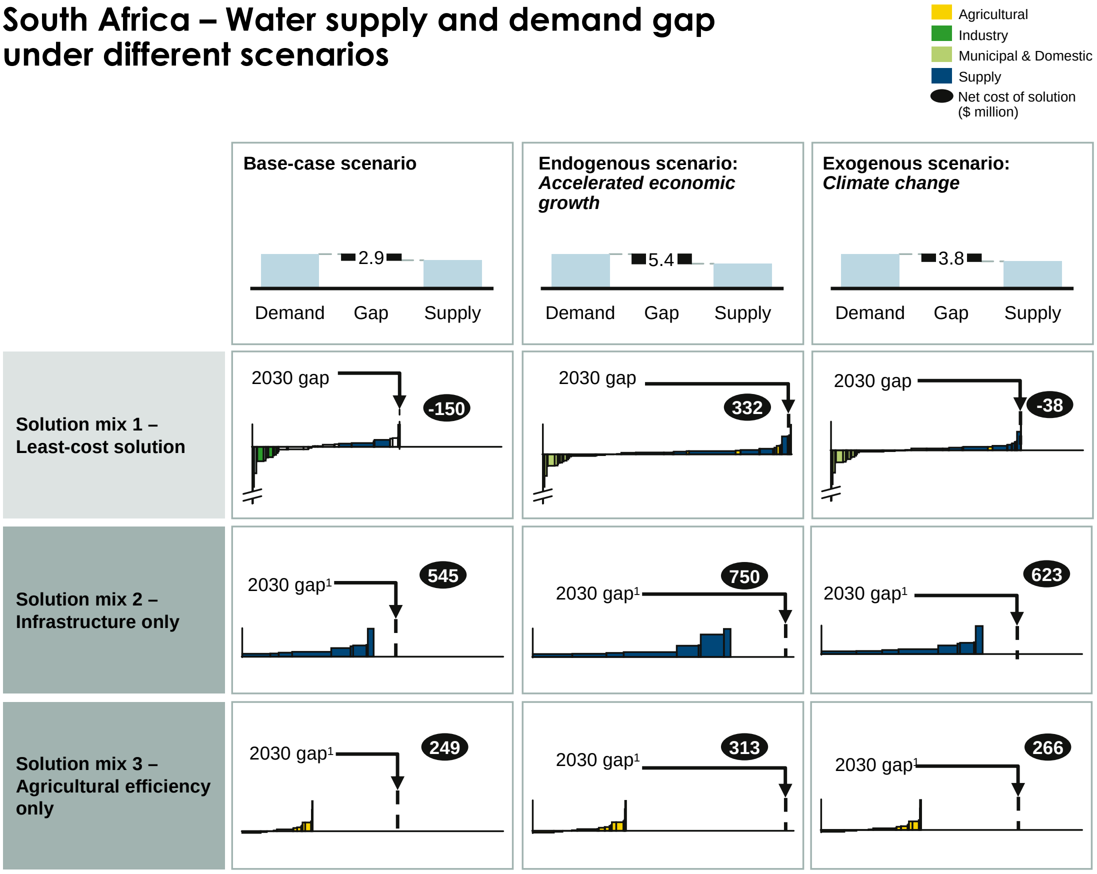
This process is not a substitute for other economic tools and analyses, nor is it a substitute for basin-level planning on the part of water managers. Rather, it provides a communicable and relatively simple picture of what the major trade-offs are and of the primary solution sets available. It also does not specify which mechanisms are most suited to enabling the adoption of a given solution. We should also emphasize that the granular nature of the analysis should not be taken to imply that it necessarily envisages a "planned solution" to close the water gap. This tool does not advocate a command-and-control solution to the water sector; it simply quantifies a set of scenarios and marks a starting point for a new quality of cross-sectoral dialogue.

As an example how such an exercise might provide useful input for a country-level dialogue, we explored two scenarios for South Africa that would produce a 2030 supply-demand gap significantly greater than that projected in the base case. The first of these explored the implications of a scenario of accelerated economic development.[25] In this case, the measures included in the cost curve, including all supply infrastructure measures assessed, would be insufficient to close South Africa's supply-demand gap; less obvious choices would have to be investigated and innovation would be required. Under this high-growth scenario, net annual cost would swing to a $330 million net cost from the $150 million net savings in the base case (Exhibit 30). The second scenario explored the economic consequences of dealing with an exogenous driver—a representative scenario of climate change[26] in the relatively early window of 2030. The climate assumptions of this scenario primarily influenced the water requirements for agricultural production, and to a lesser extent, the amount of annual surface water supply. Under this scenario, the projected 2030 water gap increases by 31 percent and the overall cost of the solution increases from $150 million net savings to $38 million net savings.

25 The scenario included the following parameters: 15 percent shift in socioeconomic profile of population, 25 to 30 percent increase in consumption per person, and 15 to 20 percent increase in industrial demand.
26 Median climate change scenario from IFPRI study (X. Cai et al, 2009)

Exhibit 30

South Africa – Water supply and demand gap under different scenarios



1 The solution is insufficient to close the entire gap. Additional measures are required.
SOURCE: 2030 Water Resources Group

Each scenario, and each choice of solution, is associated with a certain economic outlook, including levels of employment, international trade, and economic growth. A single, water-focused analysis cannot optimize for all of these factors, nor should it. However, policymakers will need to be able to lay out the broader economic benefits of each potential solution to close the country's water gap. Sometimes those benefits are easily quantifiable in economic terms, for example in the case of additional GDP growth, yet at other times they are evaluated purely in social or other terms, such as in the case of poverty alleviation.

The scenario-building exercise, and the "new dialogue" on water resource security that it creates, sets the stage for policymakers to advance specific measures and policies, and for private sector and civil society actors to design their own responses—all contributing to a shared solution. The remainder of this chapter shows how the cost curve and gap models can help each of these stakeholders inform such decision-making—and engage productively with other stakeholders to enable a shared solution.

Tools for policymakers

Governments and regulators set the context and rules by which all other participants in the water sector behave. They are also major capital providers for water solutions, and must make economic policy decisions that have very direct impacts on the water gap. Their role is a challenging one, as they must balance the demands and needs of stakeholders, evaluate the scope for additional supply and its benefits, and ensure delivery in the context of a political cycle—all with only limited information.

Governments are also likely to take the lead in driving many of the specific measures and policy changes that a stakeholder process identifies as core to a shared solution. Policymakers can use the cost curve and scenario tools in a variety of ways to assemble the fact base needed to inform such action. Here we discuss three examples:

- **Communicating the impact of policy decisions on water demand.** Demand scenarios can be introduced to illustrate how water-using activities might respond to particular policy measures, such as reducing energy subsidies or removing barriers to food imports.
- **Assessing implementation challenges of technical measures to close the water gap.** The measures on the cost curve can be illustrated in a way (such as color-coding) that communicates the institutional, capacity, policy, or cultural barriers to implementation—thus providing governments with a quantitative framework to assess which barriers are most worth investing resources and political capital to overcome.
- **Quantifying the economics of adoption for end-users.** The "payback curve", a variation of the cost curve, allows governments to illustrate the economic impact to water end-users when adopting the measures that form part of a country's least-cost solution. This curve also allows governments to quantify how policy measures, such as pricing or subsidies, might change those end-user economics.

Communicating the impact of policy changes on water demand

We have discussed how scenarios representing relevant economic and development choices facing the country can inform a stakeholder dialogue to shape shared solutions. Scenarios can also be used by government decision-makers to test and communicate the impact of specific policy interventions.

As an example, consider how policymakers in India might use the cost curve to demonstrate the likely impacts of changes in energy subsidies for agriculture. Currently, many Indian farmers rely on groundwater to meet their demand for irrigation, abstracting from increasing depths using energy intensive pumps. The energy to power these pumps comes at little cost to most farmers but at a significant cost to the state due to energy subsidies (up to 80 percent of expenditure in certain states, representing a significant fiscal burden)[27]. Because energy subsidies hide the true cost of water, farmers face little direct incentive to conserve water.

27 Bhatia, R. Water and Energy Interactions, Handbook of Water Resources in India, World Bank (2007)

Some estimates show that if some regions of India were to remove these energy subsidies, the demand for water would decrease by almost a third with total crop production decreasing by nearly 15 percent.[28] Our analysis shows that a 5 percent decrease in crop production—a more conservative scenario—would reduce India's projected water supply-demand gap in 2030 by 8 percent (from 755 to 696 billion m^3). Applying this to the cost-curve analysis shows that the cost of the corresponding lowest-cost solution to fill the gap would fall by 10 percent (from $5.9 to $5.3 billion) over the base case. The fact that closing the gap would be more affordable would come on top of the fiscal savings from elimination of the subsidy, although part of the reduced cost would be offset by the imports necessary to replace the reduction in crop production, as well as the related loss of domestic economic activity.

If subsidies were so reduced, end-user economics of the technical levers themselves would also change. Adopting specific levers, such as sprinkler irrigation, would become more attractive, yielding an additional $20/ha/year of savings in operating costs (Exhibit 31)—directly impacting a farmer's bottom-line. While a reduction in subsidies would negatively impact a farmer's aggregate income, the positive effect on productivity measures would more than compensate for these losses.

An exercise of this kind would help policymakers in India communicate three dividends of this potentially very unpopular policy change: reduced energy subsidies, higher farm incomes, and greater efficiency in closing the water gap.

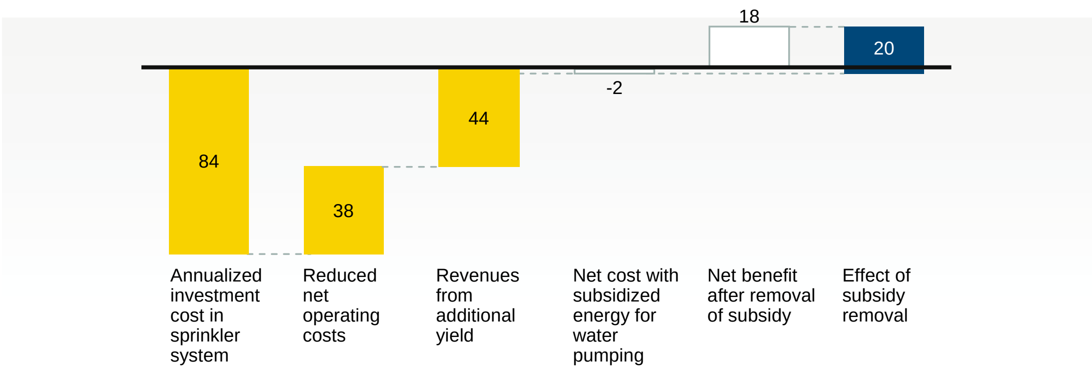
Exhibit 31

Effect of full cost of water on economics of sprinkler irrigation

INDIA

Cost breakdown of sprinkler irrigation of wheat

USD/ha/year



SOURCE: 2030 Water Resources Group

A similar exercise could be conducted to test the impact of a range of other policy measures on the water gap—such as a reduction in import tariffs on specific crops, the institution of water pricing measures, or the imposition of regulations to restrict water use (for example, to water domestic gardens).

28 Ibid

Assessing implementation challenges of technical measures

Many of the measures identified in the cost curve for a given country will require significant commitment and, perhaps, institutional change. It is important for policymakers to be able to highlight such implementation challenges in dialogue. These non-quantitative factors that might stand in the way of a solution if unaddressed, include institutional barriers such as a lack of clear rights to water, fragmentation of responsibility for water across agencies and levels of government, and gaps in capacity and information.

For example, "better tilling" may seem like a no-regrets move that can reduce water usage and overall costs in agriculture, all while boosting production. In reality, however, encouraging millions of subsistence farmers in India to adopt different farming techniques is complicated. Conversely, building a large piece of infrastructure may be expensive, but it involves much less coordination.

The analyses laid out in Chapter 3 do not account for such hidden or transaction costs simply because these are often unknown or impossible to estimate with any degree of precision, nor do they account for very real barriers such as those tied to the resistance of political constituencies which escape financial quantification altogether. Solutions that are in principle technically feasible may encounter such barriers, which—while not easily quantified in financial terms—are nevertheless very real for those charged with implementation. A full range of such challenges is shown in Exhibit 32.

Exhibit 32

Challenges to adoption

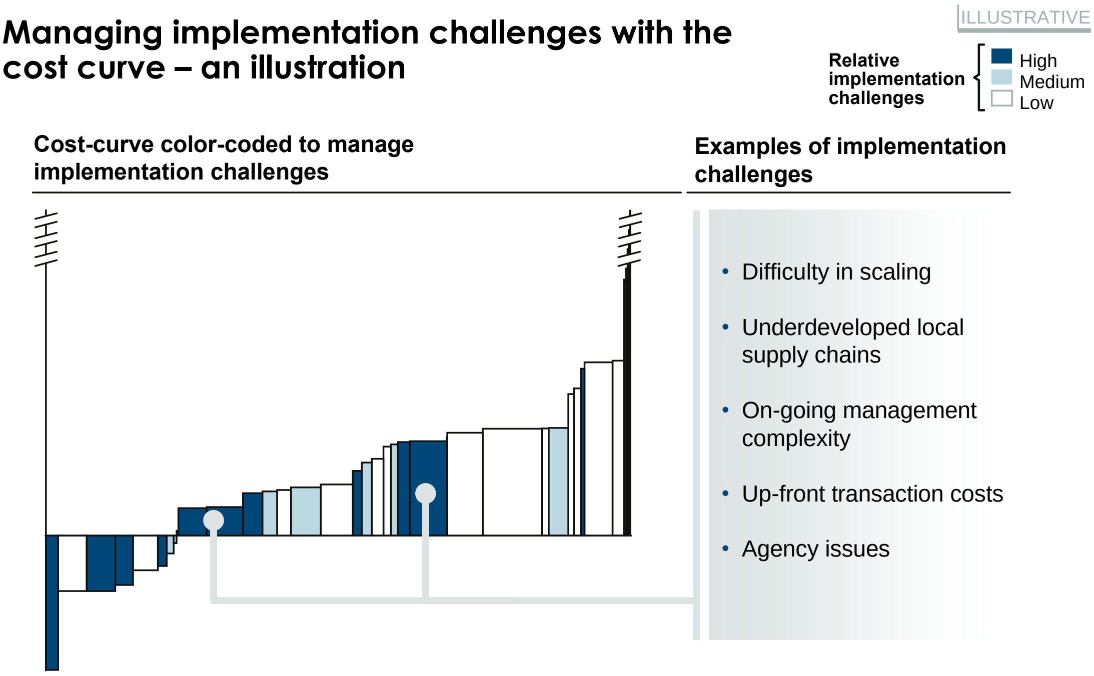
Category of challenge	Sub-category	Description
Financial	▪ Insufficient access to capital	▪ End user cannot access financial resources to pay for the necessary up-front costs of a lever
	▪ High upfront costs	▪ Upfront costs are too high even if access to capital is possible
	▪ High transaction costs	▪ The logistical cost of deploying a particular lever is prohibitively high
Political	▪ Negative impact on constituencies	▪ Certain levers (e.g., dams in specific areas) might disrupt the lives or adversely affect interests of constituents
	▪ Pricing distortion due to subsidies	▪ Levers are not attractive because end-user does not feel the impact of the true cost of water
Structural & organizational capacity	▪ Fragmentation of opportunity	▪ Certain levers require implementation and buy-in from many end-users to reach water-saving potential
	▪ Limited management capacity	▪ The existing capacity in government or private sector is not sufficient to carry out proposed projects
	▪ Unclear or fractured lines of authority	▪ The responsibility to implement a lever lies across agencies without a clear line of authority
Social & behavioral	▪ Water has low "mind-share" for end-user	▪ Improving water efficiency is not a key element of end-user decision-making
	▪ Difficult for end-user to measure consumption	▪ Lever adoption is not reinforced because it is hard to evaluate, measure and verify savings
	▪ Lack of awareness or information	▪ End-users are not aware of how a specific efficiency lever or service can be beneficial

SOURCE: 2030 Water Resources Group

Policymakers can use the cost curve to deliberate on the financial trade-offs implied by encouraging particular "solution mixes" of technical measures. Through an iterative process involving decision-makers and practitioners, each measure on the curve could be classified according to its ease of implementation and/or secondary benefits and costs, supporting an expert judgment on which measures to adopt as part of an integrated solution. The result of such an exercise would be a color-coded cost curve such as the one shown in Exhibit 33.

Exhibit 33

Managing implementation challenges with the cost curve – an illustration



SOURCE: 2030 Water Resources Group

In China and India we conducted such an exercise by grouping levers, independently of economic "sector", according to whether their adoption required few or many decision-makers, taking this as one illustration of "ease of implementation" from a public policy perspective. The result of such an exercise can help to quantify the costs of not pursuing certain sets of measures. The exercise exposed the reality that a solution made up only of those measures which required the action of a few central decision-makers would come at significantly greater cost than a solution incorporating all available measures, including those whose adoption would require changed behavior from millions of farmers and industrial or domestic water users. Avoiding these "more complex" levers and applying only the "less complex" levers would require an additional $17 billion a year in capital costs in India, while in China the full gap could not be filled at all using supply measures currently within reach—a high price for forestalling the institutional and organizational reforms needed to enable the least-cost solution. This is just one illustration. The real value of classifying levers in this way is as an aid to collaboration with the policymakers who must make the difficult trade-offs on the path to water resource security, and who will have deeper and more nuanced views of what the barriers to implementation might be.

Quantifying the economics of adoption for end-users

Financial costs that are relevant for policymakers are not necessarily the same for those—households, farmers, businesses—who will need to adopt efficiency measures or invest in supply. End-users see costs quite differently from by government, for several reasons. For example, end-users, including businesses in the agricultural, industrial, as well as residential sectors may not experience the real capital and operational costs of water supply: they may receive subsidies or pay taxes on water, and they may also incorporate revenues derived from water use into their decision-making. Their discount rates may also be higher than what would be legitimate to assume from the perspective of a government. This difference in cost perspective lies at the heart of the water dilemma, and is why understanding and quantifying the costs of adoption is so important.

Governments need to be concerned about the economics of adoption: if end-users perceive measures as providing a net benefit they are more likely to adopt them. One useful way to evaluate when a measure can be considered to have a net benefit is to calculate its payback time (see Box 6: The payback curve).

BOX 6

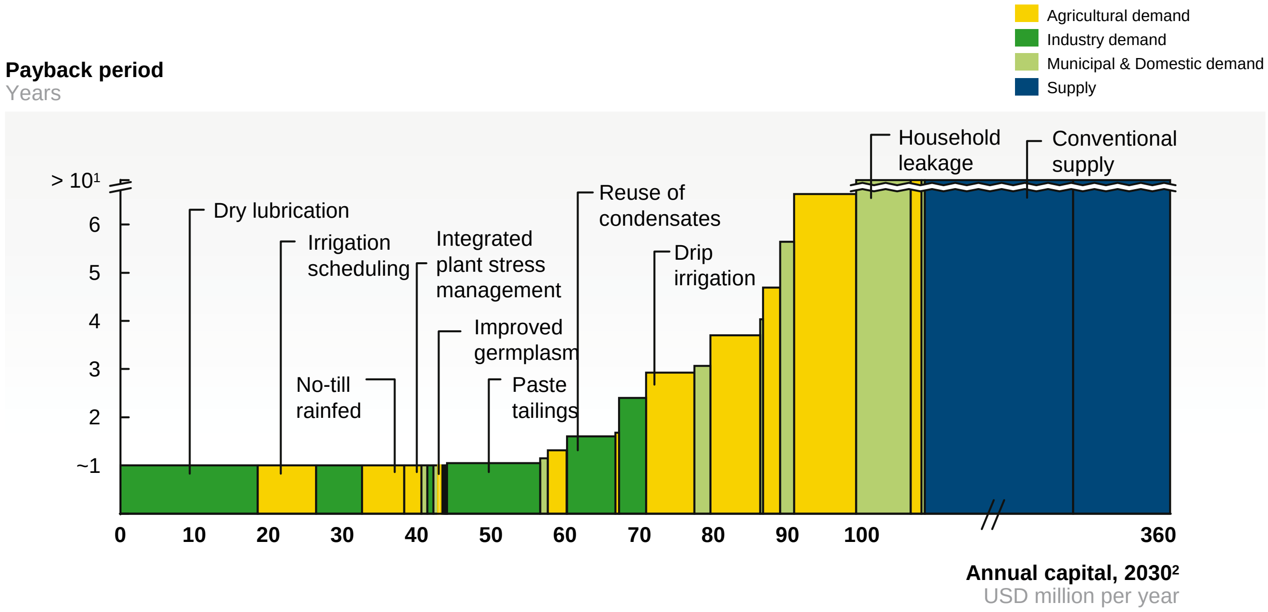
The payback curve

While the cost curve allows a comparison of measures on a "like-for-like" basis by calculating the net impact on water availability and they cost of the various measures available to close the supply-demand gap, the payback curve allows us to compare measures on the basis of their capital requirements and their payback periods—the number of years it will take for the capital expended to be recovered (Exhibit 34). This view is a better indication of what areas may yield financially attractive business models and can be applied to both demand efficiency measures and supply infrastructure. For supply infrastructure, however, the payback for the owner and operator (often the government) of the asset critically depends on a water price for revenue streams.

The horizontal axis of the payback curve shows the aggregate annual capital requirements (for both investment and working capital) in U.S. dollars in 2030. Two forms of capital are included in the calculation: capital for investment (primarily in assets) and working capital to finance operations. The latter is highly dependent on cash flows and on credit lines, but for the purposes of this analysis we have not made significant adjustments for these costs.

Exhibit 34

End-user payback curve



1 Measures with no payback (i.e. only negative cash flows) also shown as > 10 years
2 Does not include financing cost
SOURCE: 2030 Water Resources Group

The vertical axis shows the payback period of the project from the view of the adopter of the measures—such as the farmer, household, or business. While our analytical framework has been established at the sector level, and we have not undertaken to construct specific business models, or investment cases, the payback curve is a useful evolution of the cost curve toward bridging the analytical gap to deploy private sector capital. Weighed against different expectations on how quickly capital outlays need to be recovered, the payback curve helps country decision-makers understand how attractive measures are to end-users, and what incentives might be necessary.

The payback view is similar to that of the cost curve in that measures with a fast payback time also have a negative unit cost (i.e. net benefit) on the cost curve. Some measures that offer a net benefit on a unit-cost basis may nevertheless have a payback period that is not sufficiently attractive to the end-user.

Different end-users will require different payback times, implying different rates of return on capital for projects or investment cases with different risk profiles. For example, in the case of efficiency levers such as more expensive dual-flush toilets or leakage reduction programs in industry, research shows that both consumers and businesses typically require payback times of less than two years in order to adopt such measures.[29]

In dialogue with stakeholders, governments can use this understanding of the payback periods of specific measures to inform policy action. They can also create an overall picture of the payback periods required for the capital to close their country's supply-demand gap (Exhibit 35). The exhibit shows that in many cases the measures with long payback periods—many of them supply infrastructure—are also the most capital intensive ones. This likely indicates that those measures will not attract private sector capital, requiring the financial burden to fall fully on the public sector

The results of the payback analysis deliver striking regional differences. For example, in India, 75 percent of the supply-demand gap could be closed with measures that promise a payback period of less than 3 years, with the large majority in even less than one year. They are almost exclusively in the agricultural sector. According to our payback curve, this indicates a high likelihood of adoption. Non-economic barriers such as a lack of information, a highly fragmented user base, capital constraints, and limited access to finance impede broader implementation today. Of the remaining gap, 19 percent of India's least-cost set of solutions lies in supply-side infrastructure with an inherently longer payback period.

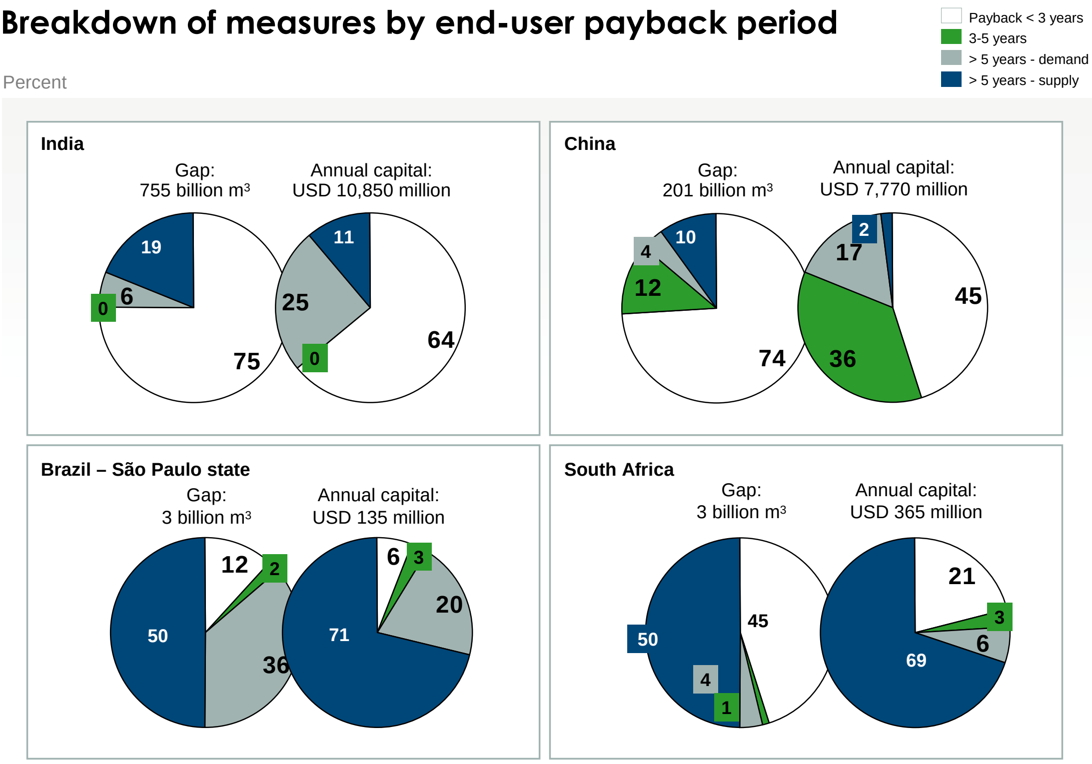
29 McKinsey research on the required payback in the U.S. commercial sector consumers on energy efficiency investments in 2007 revealed that 73 percent of users will disregard energy-efficiency investments with a payback time above 2 years.

In South Africa and Brazil, longer payback supply measures will be required to close the bulk of the gap. Supply infrastructure would close half of the gap in both countries, and accounts for more than two-thirds of their annual capital need to 2030. Nonetheless, most of the remainder of the gap in South Africa can be closed with measures that have a payback of less than 3 years. They are mainly industrial water efficiency improvements, such as paste-tailings in mining and dry lubrication in the beverages and other industries. Efficiency measures in São Paulo state, such as water-efficient toilets and leakage reduction in industry, come with longer payback periods. If these measures are to be widely adopted, end-users will require stronger signals—both in terms of pricing and public information—to show that water efficiency is important.

Exhibit 35

Breakdown of measures by end-user payback period

Percent



SOURCE: 2030 Water Resources Group

This analysis could be used to help governments distinguish between those measures that need greater economic signals in order to be adopted, and those that, on paper at least, represent areas where private sector investors may be willing to play a role. However, even for such economically beneficial measures, governments may need to address existing barriers to adoption. For example, agricultural technologies may very well be beneficial for most farmers, with positive business cases for the end-user, but a lack of access to credit for small-scale and marginal farmers could make realizing those gains virtually impossible.

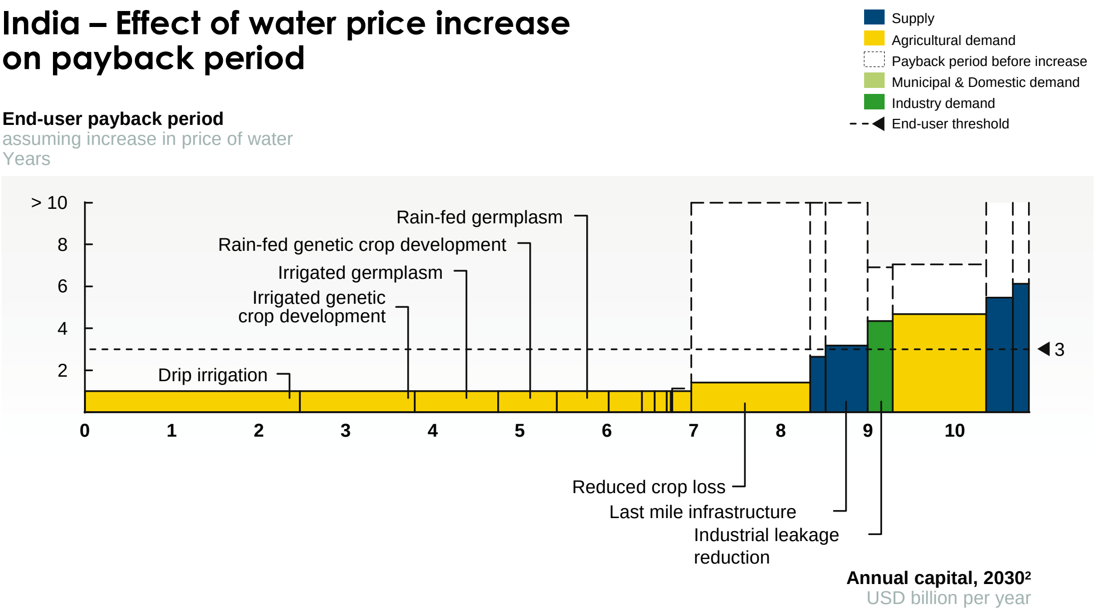
Countries rarely adopt a planned approach where top-down mandates determine what is produced by the economy, and thus the economy's overall water intensity. Rather, the policy answer is likely to center on regulatory frameworks that set the context within which individual producers operate and create incentives for these producers to move in the direction set out by policymakers. Policy levers such as taxes and subsidies can impact the economics of adoption and therefore facilitate the scale-up of particular measures.

Water prices also impact the economics of these measures. A water price can be obtained in many ways—for example, by establishing water access rights, setting a cap on allocations, and creating functioning water markets to efficiently allocate water to uses.

Governments can model the impacts of such policy measures on the cost curve. For example, in India an increase in the price of water by $0.05/m^3 increases the share of measures with a payback period of less than 5 years from 75 to 94 percent (Exhibit 36). At the same time, it improves the financial attractiveness of key measures: opportunities such as industrial leakage reduction and many supply-side measures now see the financial incentives required to attract private capital.

Exhibit 36

India – Effect of water price increase on payback period



1 Measures with no payback (i.e. only negative cash flows) also shown as > 10 years
2 Does not include financing cost
SOURCE: 2030 Water Resources Group

Where water prices are kept artificially low for domestic and industrial users, they increase the payback period of efficiency measures. As a consequence, efficiency or productivity measures often look less attractive to the end-user of water than they do from an integrated perspective.

Low cost recovery from supply does not incorporate the true cross-sectoral benefits of providing water to its users. However, for private investors and operators to be mobilized to contribute to water security, the water tariffs that suppliers receive as revenues must be sufficient to ensure reasonable returns on their operations. As an alternative, the public sector can step in to bear the cost, circumventing the barriers in the private sector (Chapter 5 discusses these prices and tariffs as potential instruments in further depth.)

Pathways for the private sector

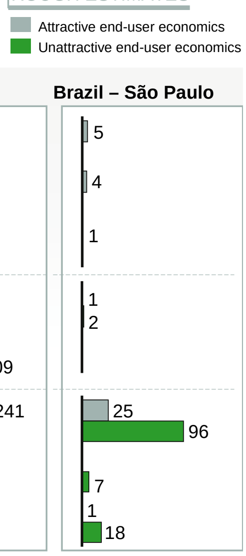
How should the private sector engage given the insights from the cost curve and demand scenarios? First, in each country, the potential for reducing the gap between supply and demand comes from different private sector segments. The analysis of end-user economics in each case study shows that in principle there are measures to close the gap that are beneficial for the end-user and represent an opportunity for the private sector today (Exhibit 37). Beyond the base-case scenarios, further policy intervention by government, as discussed in the section above, could make further measures economically attractive for the private sector, and thus unlock new investments. The cost curve thus empowers the private sector to engage meaningfully on defining the institutional mechanisms of the future.

Exhibit 37

Incremental annual expenditure by 2030[1]

ROUGH ESTIMATES

USD millions



1 Based on the least-cost solution to close the gap
2 Equipment, procurement, construction
SOURCE: Water 2030 Team

The cost curves developed for each country provide new transparency on where the opportunities lie for private sector investment in and adoption of water security solutions. In this section we analyze some of the bigger opportunities, focusing on five important sectors:

Agricultural producers and other agricultural value chain players. Food production and the water it requires are a key part of the water challenge. Some 70 percent of the world's water use is in agriculture—with the implication that farming plays a very important role in ensuring that water is available for all uses. The agricultural water solutions shown in the cost curves address both the water challenge and the food challenge, and represent a comprehensive suite of existing techniques and technologies that farmers, together with other value-chain players (such as food processors) and policymakers, can use to improve agricultural productivity.

Financial institutions. There is wide agreement that water has suffered from chronic under-investment. Financial institutions are likely to be an important actor in making up this shortfall and are already investing in desalination, treatment technologies, and general supply measures. The cost curves provide such institutions with an initial map to understand where their services may be most needed, and where value could be created through the adoption of specific measures.

Large industrial water users. The nexus between water and energy, and between water quantity and quality is at the heart of the water challenge, as we have seen in China and Brazil. These issues are particularly relevant to large industrial users such as metals, mining, petroleum, and energy companies. The transparency provided by the demand and supply analysis, and by the cost curves on where they are most exposed to the risk of water scarcity, and what their options are to mitigate the risk, will assist such companies in making the case for investing in water security solutions.

Technology providers. Innovation in water technology—in everything from supply (such as desalination) to industrial efficiency (such as more efficient water reuse) to agricultural technologies (such as crop protection and irrigation controls—could could play a major role in closing the supply-demand gap. Also, many of the solutions that populate the cost curve imply the scale-up of existing technologies, and such a scale-up requires expanded production on the part of technology providers. The cost curves provide a framework that technology providers can use to benchmark their products for an estimate of their market potential and cost-competitiveness with alternative solutions.

Construction sector. A renewed interest in water use efficiency does not mean that supply measures do not have an important role to play, as we have seen in Brazil and China. The construction sector will need to continue to deliver those large-scale infrastructures. The cost curves provide transparency on where such infrastructure is most needed, and where alternative solutions may prevail.

Agriculture and food value chain players

Food production and the water it requires are a key part of the water challenge. Food self-sufficiency in countries with rapid population and income growth will become an increasing challenge. Some 70 percent of the world's water use is in agriculture—with the implication that farming plays a very important role in ensuring water is available for all uses. In the countries we have analyzed, agricultural efficiency—and even more importantly productivity—will play a central role in achieving water security. The magnitude of the potential impact of these solutions on both challenges should motivate farmers, other agricultural value-chain players (such as food processors), and policymakers to jointly encourage their implementation. Water efficiency in agriculture is relevant for irrigated agriculture, where the same or greater yield can be produced with less water. Agricultural productivity on the other hand is relevant for both irrigated and rain-fed agriculture. Maintaining rain-fed land and improving its productivity is particularly important, as any rain-fed production avoids water abstraction for irrigation needs. In India, we found that 17 percent of the total potential for agriculture to solve the gap comes from improvements in rain-fed production. This large opportunity includes practices such as improving the fertilizer balance on fields, integrated pest management, and improved drainage systems. In South Africa, nearly half of agricultural potential comes from productivity increases on rain-fed land. As an important aside, if yield improvements are going to have a true impact on water, they must absolutely be reflected in land intensification, which saves land for other purposes.

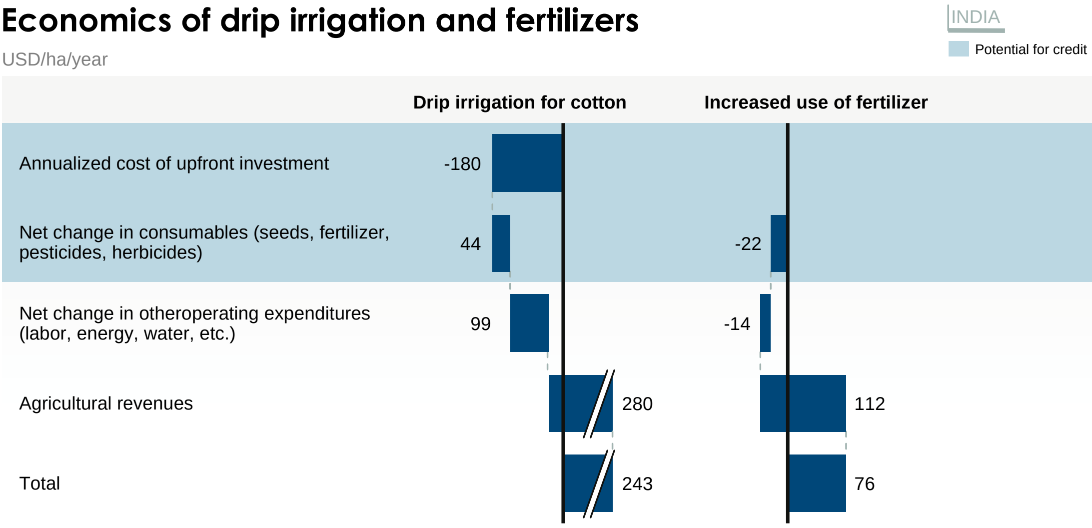
The agricultural measures modeled on the cost curves can greatly enhance agricultural incomes. In South Africa, aggregate agricultural income could increase by $2 billion per year from operational savings and increased revenues, if the full potential of agricultural measures were mobilized. In India, where agriculture plays the most important role in the least-cost solution, aggregate agricultural income could increase by $83 billion per year by 2030. Drip irrigation alone has the an aggregate potential to increase revenues by some $30 billion annually and create net savings for India's farmers, if the full potential of 37 million hectares is utilized. This large potential arises from two combined effects: reducing the amount of fertilizer required by up to 40 percent, and increasing yield by up to some 60 percent. The use of better seeds on both rainfed and irrigated land, meanwhile, can increase Indian agricultural incomes by $25-30 billion annually. One caveat: *this analysis does not identify the optimum agricultural outcome, but simply shows that a sustainable water outcome also benefits agriculture significantly.*

Limited uptake of these technologies today shows that they require the support of enabling supply chains, as well as policy assistance for technical and financial innovation. For example, very different economic structures are required for relatively capital-intensive measures like drip irrigation compared to measures relying only on consumables, like the increased use of fertilizer, but both nonetheless share their need for upfront financing: for drip irrigation, to buy the equipment, for fertilizer, to bridge the time between fertilizer needs to be bought and revenues are made from crop production (Exhibit 38). Innovative forms of micro-finance and insurance are needed to address the limited cash flows of smallholder farmers, and to mitigate the risk of crop failure if cash-constrained farmers are to spend more money on seeds that promise higher yields. In addition, modern seed varieties, fertilizer, and agrochemicals critically depend on the supply chains that make them available to distant rural areas. Importantly, though these are techniques ultimately employed by the farmer, other agricultural value-chain players such as retailers and processers can help transfer technology to their suppliers. The *Better Cotton Initiative*, a textile retailer-sponsored effort which helps train farmers in best-practice efficiency techniques in irrigated areas, is an innovative example of this.

Exhibit 38

Economics of drip irrigation and fertilizers

USD/ha/year



SOURCE: 2030 Water Resources Group

In facilitating these developments, tough decisions at the public policy level will have to be worked out in concert with producers. With individual farmers increasing land and water productivity and output, either increased production overall will occur which negates the water savings from the measures, or marginal farm labor will need to be redeployed elsewhere in the economy.

Similarly, in many cases, it may be more efficient to specialize and deliver high-value crops where water is limited, with grain production to be relocated to areas where water is less scarce. An examination of crop requirements in Saudi Arabia, for example, show that some 30 percent of water demand can be eliminated simply by importing alfalfa, yet at the expense of livelihoods supported by agriculture. In India, the difference in the least-cost solution between an optimization at the national and the basin level—which costs $1.4 billion more to implement annually—poses similar questions. What is the impact on farmers of intensifying agricultural production in some parts of the country which marginalizes production elsewhere in the country? How should policymakers anticipate such a change?

While the levers on the cost curve represent a thorough scan of the main measures available to us, some of the agricultural measures in particular move further into the agricultural value chain and could be investigated further—for example, the reduction of waste in the agricultural supply chain after leaving the field. When agricultural products are lost during harvest or in transport or storage, water—or virtual water—is essentially wasted. The global breadth and size of modern agricultural logistics and supply chains make such waste difficult to estimate accurately in a national context, or to attribute directly to a particular basin gap. A partial analysis of some of these levers (for example, on-field, pre-harvest and post-harvest treatment), found that a reduction in waste could indeed help reduce India's water gap by a combined 10 billion m^3 in 2030, but at high costs relative to others (0.07/m^3 and 0.11/m^3 respectively). Low-technology methods for reducing losses in transport and storage could also have impact—averaging 0.04 / m^3 in India. Deeper research is needed into measures to reduce losses throughout the transport, storage, and market value chain, and especially into mechanisms to ensure that the reduced losses have an impact locally.

Financial institutions

Financiers can participate in the water market as lenders and equity holders. As such, they are the providers of capital for the sector, especially in those cases where the public sector is unable to appropriate sufficient funds. Increasingly, lenders and investors see the water sector as an area of interesting investment. The tools and data developed in this report can help them identify potential opportunities, although it should be very clear at the outset that these tools cannot and do not substitute for specific business cases

By converting the cost curve to a payback curve, investors are able to identify capital-intensive measures that may require the participation of a financial institution. In some cases that capital is invested in assets, in other cases it is required as working capital. While this is a relatively blunt economic and sectoral analysis it does provide information that can guide further investigation in specific classes of measures.

In India, the measure identified which in aggregate requires the most capital is drip irrigation, with projected annualized capital expenditures of $2.4 billion in 2030. More detail on this specific opportunity is provided in Box 7: Drip irrigation in India—a possible investment case.

BOX 7

Drip irrigation in India—a possible investment case

Drip irrigation for Indian agriculture has a technical potential to cover 37 million hectares by 2030, up from only around 2.5 million hectares in 2005. Today, micro-irrigation systems (MIS) have a market size of approximately $400 million in India of which some $230 million is drip irrigation systems. MIS grew by 15 percent per year between 1999-2006. If the full potential were realized in 2030, drip irrigation would have an annual growth rate of 11 percent leading to a market size of approximately $2.4 billion per annum.

Increasing pressure on water resources, coupled with GDP and population growth, are likely to require significant productivity increases in Indian agriculture and hence greater adoption of drip irrigation. Through the Accelerated Irrigation Benefit Program (AIBP), the Indian government has already started supporting adoption in the attempt to accelerate irrigation growth. An additional $206 million has been allocated via interim budgetary estimates for the AIBP, marking an increase of 75 percent over the allocation in 2008-09.

The sources of value for the investor lie in the increased revenues that drip irrigation will create for the farmer, through reduction in input costs, such as fertilizer used per hectare, and increased yields by up to 50 percent, depending on the crop. The investor can access this value as an equity holder in a company operating in the drip irrigation value chain, or as a lender.

As an equity investment, today's market is far too small to communicate anything meaningful about the market in 2030. It is a highly fragmented market with approximately 70 players, mostly small and local, but with the two top two players accounting for around 80 percent of the market. As of today, there is limited competitive pressure due to strong growth and mostly small competitors, and as a result the profit margins are high, 10 to 20 percent making equity participation potentially attractive. Equity could also take the form of participation in businesses offering related services, which would include installation and maintenance, repair, training. Current penetration and growth of drip irrigation is highest in high-value horticultural crops,

In China, the largest capital need is in municipal leakage reduction, which has a technical potential of 9.2 billion m^3 per year, is $1.8 billion of annually. With a 22 percent rate of return, the efficiency opportunity is attractive for municipal utilities. The biggest constraints to broader network rehabilitation and pipe replacement currently are a lack of awareness among utilities of the benefits of leakage reduction, in some cases limited pressure to operate profitably and thus corresponding limited efforts to secure funding for leak detection and repair programs.

which would suggest that its success partly depends on a progressive conversion to higher-value agriculture. However, strong growth in other crops is likely given government's increased focus on agricultural productivity and diminishing availability of water.

The question of which business model might allow for scale-up required remains unanswered. Today, companies sell through dealer networks who are often farmers, and successful players incorporate a full range of services including system design and training and end-to-end packages that assist farmers in system design and use.

The scale implied by our models assume a distribution network capable of reaching distant smallholder farmers, and one where farmers' high price sensitivity combined with competition has not eroded all margins.

From the point of view of the farmer, the capital required to install drip irrigation has a payback period of only one year. But with an upfront cost of some $1,000 per hectare, the technology is capital-intensive and much too expensive for many smallholder farmers to adopt without subsidies, even at an annualized rate of $180 per hectare for loan repayments, as shown in Exhibit 42 above. An alternative model of participation for example, is *investors as lenders*, assisting farmers in bridge-financing until subsidies are received from the government.

There is a clear demand for capital and a direct source of value creation. What prevents private sector lenders and financiers from participating more widely? Lending directly to farmers would require innovative means of providing broad access to micro-finance in distant rural areas. Participating in this market would thus require local partners who have the reach and access needed to achieve impact. Increasingly, flexible payment terms are also being offered by producers of irrigation systems, offering potential opportunities for partnering with them to ease the initial capital costs to farmers.

With only limited private lending opportunities to public sector utilities, the most prominent opportunity for participation of financiers is through equity stakes in the businesses serving utilities and supplying the markets. This includes manufacturers of equipment and pipes, a very competitive market in China, and service companies that engage in the public bidding contracts of utilities. Innovative technologies are emerging to detect and repair leaks that are offering easier use at lower cost. Services are increasingly being offered to utilities against a share of the savings achieved, rather than against fixed payments. However, the market remains very fragmented and the businesses providing these services are mostly small providers, serving only their immediate local area.

In the cases of South Africa and São Paulo, transfer schemes form the largest opportunity in both geographies with a technical potential of 800 million m^3 per year by 2030 in the least-cost solution. The related annual capital need is approximately $180 million to $200 million per year. These investments have typically fallen into the realm of the public sector, offering little economic incentive for participation in the absence of suitable water tariffs. Nonetheless, there could be a role for private investors in one of two forms: either as traditional project financing extended to public borrowers, or in more innovative forms of equity stakes in build/operate/transfer- models already common in urban water supply. Of course, the latter would require significant shifts in policy, allowing private investors to own raw water infrastructure and to charge tariffs that fully recover cost for the water the infrastructure supplies.

It is clear from these examples that government collaboration is needed to unlock investment by financial institutions in water security solutions. In some cases, the government is party to the transactions involved in these opportunities. In others, it sets the policy framework within which financiers act. The cost curve may provide the basis for discussions on these principles, but a deeper analysis is required to properly gauge the full picture in each individual situation.

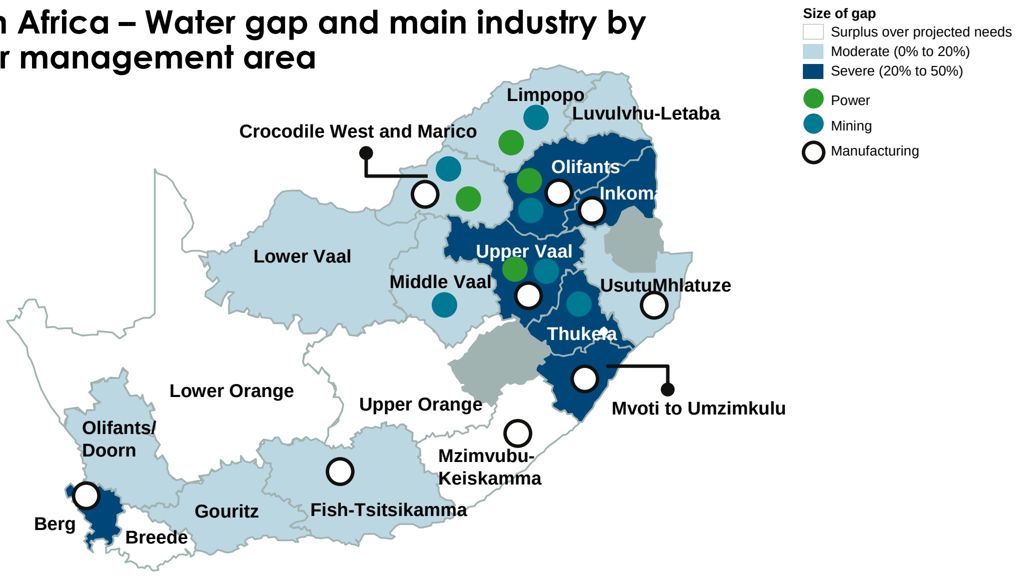
Large industrial water users

The gap between demand and supply in 2030 outlines the risk of water scarcity to which an industry is exposed in a particular basin, as well as its own role in driving demand. In South Africa, for example, the projected supply-demand gap as a fraction of total demand is most severe in the basins where urban and industrial growth is greatest (Exhibit 39). In the Upper Vaal, where the gap is 33 percent, industry makes up 44 percent of total water demand in 2030. In Mvoti-Umzimkulu, which has the greatest gap at 46 percent, one-quarter of demand is industrial. In both basins, industrial demand outgrows demand in other sectors, therefore expanding the gap.

Similarly, in the Brazilian state of São Paulo, even a 7 percent gap in 2030 could have a significant impact on industry operations in the water management area of Mogi-Guaco, where 70 percent of water demand is industrial, driven by ethanol and pulp and paper production. In petrochemicals, conglomeration economics are huge, and thus water demand is very concentrated in two basins, Alto Tietê and Piracicaba/Capivari/Jundiaí, which are already water-stressed areas.

Exhibit 39

South Africa – Water gap and main industry by water management area



SOURCE: National Water Resource Strategy; DWAF; 2030 Water Resources Group

Risk of scarcity is increasingly affecting decisions on where to locate industrial plants, and may negatively impact industry operations, as recent examples in power generation illustrate. For example, in Spain in 2006, the largest nuclear plant was forced to shut down due to the high temperatures recorded in the Ebro River. In late 2007, the Tennessee Valley in the United States experienced a severe drought, with the inflow to reservoirs 67 percent below normal levels. As a consequence, the Tennessee Valley Authority had to interrupt its hydropower production and was forced to source 14 percent of its required power from pricier outside suppliers. South Africa is facing a similar strain, as increasing power demand faces low water availability, especially in the northeastern basins where coal deposits will likely direct the location of power stations.

Choice of technology is also affected. For example, in power generation flue-gas desulphurization (FGD)—a technology for eliminating sulphur and nitrogen oxides (SOx, NOx) from power station emissions—increases water requirements. Where environmental regulation commands use of FGD, an implicit trade-off is made between water conservation and other environmental targets. Currently, there is no such regulation in South Africa, although this may change. In some cases, however, choice of technology aligns with multiple environmental objectives. For example, in the choice between pulverized and fluidized bed combustion, the latter is the clear winner in terms of water consumption, energy efficiency, and pollutant emissions.

Water quality is also imposing new constraints on industrial water users, affecting both the availability of water of sufficient quality for their own demand and the discharge of wastewater from their operations. In the China's Hai Basin, for example, 54 percent of surface water is of such poor quality that it is non-usable. Such pollution has two impacts on industrial water users: it further increases the risk of water scarcity by greatly limiting supply alternatives; and it increases the pressure on industry to improve the quality of the wastewater it discharges.

Industry therefore has a real interest in the policy decisions made about the management of water resources, and it has a vital role to play in the sustainable use of water. Some 15 percent of the least-cost solution in South Africa depends on industrial efficiency opportunities. In Brazil, this share stands at 10 percent overall, and 22 percent in the Mogi-Guaco water management area. The cost curves will help stakeholders understand the potential strategies and how industrial levers can mitigate the risk of scarcity.

In some cases, the cost curves show that low-cost alternatives are available to industry to reduce its water footprint. In the mining industry, for example, which in South Africa makes up 18 percent of the total industrial water demand in 2030, paste-tailings offer significant water productivity increases. Paste-tailings refer to a method of thickening tailings, the residual, solid material remaining after recoverable metals and minerals have been extracted from mined ore, from any remaining process water. The opportunity has the potential to fill 4 percent of the gap in South Africa, or 125 million m^3 annually. It offers savings of approximately $0.60 per m^3 of water, at payback periods of 1 to 2 years.

In other cases, low-cost solutions may not be available to industrial users. Industrial leakage reduction in Brazil, for example, comes at zero net cost to businesses. But at a payback period of just under 7 years, it is not sufficiently attractive for businesses to dedicate attention and resources to adopt the measure.

In such cases, the cost curve may point to lower-cost alternatives in other sectors. Businesses can then engage other stakeholders—if water rights are established, by buying water from them. In the absence of such institutional settings, businesses might pay for lower-cost agricultural water savings for nearby farmers in exchange for being allowed to use the saved water in their own operations.

The information generated by the cost curve helps businesses to design their water strategies around locations less exposed to risk of water scarcity, technologies that reduce the industry's footprint, and options to increase the available supply through engaging other stakeholders. It also serves as a fact base for discussions with policymakers on the implications of sectoral policies on the business.

Technology providers

Technology providers are central to unlocking greater efficiency in industrial and other uses of water. However, in a fragmented institutional framework governing the water sector, long-term innovation and product development take place in a world of uncertain returns. As a consequence, water technology has traditionally not been driven by a global resource economics view and water technology has often been the by-product of other sectors, such as energy.

Yet the water sector provides tremendous opportunities for technology providers to “define” the options available on the cost curves. The cost curves can help inform technology providers of the relative position, cost, and opportunity of their technologies, compared to efficiency and supply alternatives. They can show the sensitivities of demand as a function of cost improvements that may be achieved in the technology. And they can provide benchmarks for the introduction of technologies that are not yet featured in the cost curves. Particularly where cost curves are steep at the margin—as is the case in South Africa and Brazil—there is significant room for innovation to deliver lower-cost solutions.

Desalination, for example, is growing fast globally. However, with its high per-unit cost, it only forms part of the least-cost solution in some basins of the South Africa case study, with unit costs of between $0.60 and $1.30 per m³. Expansion of desalination at times of energy scarcity therefore calls for further improvement of the most efficient available technologies, particularly membranes that lead to an improved energy efficiency, and energy recovery systems. Such improvements could bring costs of desalination to ~$0.50 per m³ by 2020.

In extremely arid regions such as the Arabian peninsula, the potential for additional, next-generation technologies is starting to emerge, including such technologies as zero water discharge schemes or the use of sea water for toilet flushing. The cost curves set the benchmark against which these technologies have to perform, and they can provide a basis on which their prospects and benefits can be discussed with policymakers to foster support.

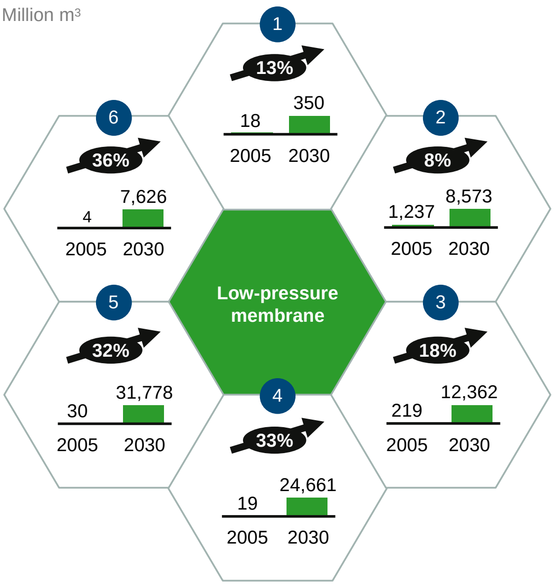
In China, membrane technology has the potential to play a critical role in addressing the challenge of water quality that goes beyond the immediate challenge of making enough quantities of raw water available for the different users. Today, the penetration of wastewater treatment is low, even leaving around 15 percent of wastewater treatment plants under-utilized as the networks are lacking to collect and transport the wastewater to plants. Rising environmental pressures as well as limited availability of additional water supply in water-scarce basins like the Hai, Huang, and Huai basins makes wastewater treatment—and wastewater reuse—an increasing concern and major challenge for China over the coming decades.

At between $0.50 and 0.70 per m³, membrane technology today is still some two to three times more expensive than traditional, more-prevalent bio-treatment technologies. Membrane technology offers superior quality, making it particularly relevant for environmentally-sensitive areas such including water derived from industrial development areas and decentralized treatment, and reuse. Naturally, estimating market sizes out to 2030 requires making a number of aggressive assumptions. Our assumptions for impact on China's water situation combined with insights on sub-markets, point towards a market for low-pressure membranes in China that could serve a volume of 85 billion m³ by 2030, 56 times the 2005 volume. The most striking increases will occur in municipal clean-water treatment, the largest segment in 2030, reflecting an annual growth rate of over 30 percent between 2005 and 2030. (see Exhibit 40).

Exhibit 40

Market size of low pressure membrane by application

Million m³



Desalination

1. **Pretreatment** of RO in SWRO process

Industrial use

2. **Pure water pretreatment** of RO in making pure or ultrapure industrial water
3. **Wastewater** (pre-) treatment of RO in industrial wastewater reuse

Municipal use

4. **Advanced treatment of potable water** after conventional treatment technologies
5. **Advanced water purifier** to convert municipal wastewater to reuse level; membrane in MBR technologies
6. **Additional wastewater treatment for reuse** to directly potable water

SOURCE: 2030 Water Resources Group

Construction sector

While a solution focusing on additional supply is much costlier to a country than a least-cost solution including efficiency measures, supply infrastructure continues to play an important role in the least-cost solution of each country.

Our cost curves show that in South Africa and São Paulo state there is potential for the construction of supply infrastructure, although relatively small. Overall, engineering, procurement, and construction in large-scale water supply infrastructure for domestic, industrial, and agricultural use will account for $250 million in South Africa invested annually in supply infrastructure, with related operations and services representing a further $40 million. The equivalent figures for São Paulo are $120 million and $10 million.

In India, the rehabilitation and last-mile completion of irrigation infrastructure can address 14 percent of the existing gap, which if implemented, translates into annual expenditures (and therefore revenue potential) of $1.4 billion annually.

That these options are at the margin of the least-cost solution implies a risk for the infrastructure to become stranded assets—a relevant risk for companies also involved in the operation of the asset, for example through build/operate/transfer-type contracts. This may happen if new technologies significantly increase the productivity of water use, or if economic shifts change the pattern of consumption.

There may, however, also be significant upside potential for the construction sector. New dams, for example, have additional benefits that may help their prioritization by governments: India, for one, has significant needs for flood control and the peak-power generation that hydropower can provide.

Infrastructure will also be required for inter-basin transfers that form part of the least-cost solution in some countries. In South Africa, for example, out of a total potential of 950 million m^3 for transfer schemes, 350 million m^3 of additional water—12 percent of the gap—can be supplied via inter-basin transfers as the least-cost solution. From a pure cost perspective, in the Upper Vaal, the 200 million m^3 of water annually transferred via a gravity scheme from Upper Orange is a lower-cost alternative to efficiency and productivity measures such as rainwater harvesting and improved integrated pest management.

The role of civil society

Water has benefits that the measureable withdrawals for consumption by its different users do not capture, and the choices on the management of water resources affect civil society in many ways. The analyses in this report provide a starting point for civil society to engage in discussions on the choices and limitations of different solutions to address water scarcity.

Economic development is clearly in the interest of any country. But it is also important for civil society to understand what the effects growth and the corresponding societal trends have on scarce resources in the country, and what options could address these. For example, urbanization and the change of diets are trends generally related to economic growth. In South Africa, we saw that unexpectedly high economic growth would result in a near doubling of the gap, in part driven by such societal changes. As we have seen, addressing the gap would then be turn from a net benefit of $150 million annually into a cost of $330 million, without even fully closing the gap. This is not to suggest that as a consequence, South Africa should stop growing or dictate diets to its population. But creating transparency on the challenges that societal trends might have on water, and to engage civil society, is important to be able to manage the responses they require to close the gap.

Similarly, the different options on how to close the gap can have strong implications for society and the workforce in a region. First, finding solutions at the national level compared to the basin level implies that water-intensive economic activities best follow where water is available. As outlined in the case of India, this could imply a shift of agricultural output from water-scarce regions to the relatively water-abundant Ganges River Basin. Second, a choice for individual levers can have significant consequences on employment. Productivity increases in agriculture have the long-term effect of reducing the agricultural workforce needed to meet demand. The equipment and material needed, on the other hand, can create employment in the supply chains requirement. Building new dams requires a workforce for construction and operation, and might create local jobs through economic multiplier effects. All these decisions require the participation of civil society.

Finally, environmental services are another important consideration. Environmental flows require that water resources be "set aside" before any decision is made on how water demand and supply can best be balanced. The Rio Grande River basin of North America provides a telling example of what may happen if environmental flows are not considered: the river fails to reach the Gulf of Mexico frequently since its flows are over-allocated for use by both the United States and Mexico. A more sustainable approach would require that the multiple users along the river renegotiate their rights to allow for consideration of environmental flows.

South Africa has already set high ecological standards for its rivers. It allocates 20 percent of flows as a minimum for the environmental sustainability of a river. Without commenting on whether this is a high or a low number, our analyses show that in a scenario of accelerated economic growth in South Africa, demand for water will increase, nearly doubling the projected supply-demand gap in 2030 to 5.4 billion m^3. In the absence of a policy to control water demand, and the informed scrutiny of those who have non-market goods as the focus of their activities, there is a high risk that such accelerated economic growth would neglect the important convention of "setting aside" environmental flows from sources of supply and endanger them. All these developments require the active participation of civil society, be it in the form of individuals, activist groups, or non-governmental organizations. A fact base on the choices available to manage water is a strong foundation for such a discussion, and an imperative to move forward based on a mutual understanding of the challenge.

Chapter 5
Unlocking water sector transformation

- An integrated agenda for water sector transformation
- Describing the end state: A fact-based approach
- Market design and economic intervention
- Institutional transformation
- Mobilizing the private sector

Chapter 4 argued that generating a full set of options to deal with the water challenge requires a "new dialogue"—a process involving stakeholders and decision-makers across the economy. And it showed how governments, private sector actors, and civil society organizations can contribute to creating pathways to water resource security.

This chapter lays out what the key steps in that process might be, including shaping an integrated agenda for water reform; defining a quantified vision for water security at the country or regional level; designing economic interventions and market mechanisms; transforming institutions; and mobilizing the private sector.

An integrated agenda for water sector transformation

Stakeholders in most countries already accept that "business as usual" is no longer an option in the water sector. The beginnings of change are under way and there is good reason to believe that water will be an important investment theme for public, multilateral and private financial institutions in the coming decades. But although affordable solutions are in principle available to close the projected water supply-demand gaps for most countries and regions, institutional barriers and implementation challenges divert decision-makers across all sectors from achieving integrated resource management.

Existing institutions, which formally and informally regulate the water sector, are not likely to lead to an efficient solution as of today. The conditions for optimal equilibrium that economists would expect from individuals and markets attempting to maximize utility are simply not there: information access is imperfect, competition in service provision seldom exists due to water's monopolistic nature, and water scarcity is still essentially an external cost. Under these conditions, it is unlikely that the projected gaps presented in Chapter 2 will be closed effectively and efficiently without intervention.

Overcoming these barriers will require persistent action and, in many cases, an integrated agenda of water sector reform—an accelerated transition to more prudent management of a scarce and precious resource. This transition will require a level of commitment, planning and resources that will be difficult to mobilize. While in theory adequate design and implementation of regulatory frameworks should be enough to obtain the desired effects, in practice transforming an underperforming sector requires much more: building momentum, engaging stakeholders, as well as designing regulations and institutions.

This report does not presume to be a complete guide to water sector transformation. However, the frameworks and tools developed here can be effective aids in embarking on such a process. In particular they can help to:

- Design a **quantitative vision** for what the water use of a country might look like, and what it would take to reach sustainability, helping align stakeholders around a shared vision

- Identify where the **likely failures of current** economic regulation and institutional capabilities could reside, and give some indication on how those failures could be resolved
- Identify which **key stakeholders** should be mobilized—where private capital could help most, which large water users are most critical to the solution, and which technologies might be most needed

Persistent action must rely upon a commonly agreed fact base, around which reform processes can take shape. Water is a cross-sectoral issue, a fundamental piece of the infrastructure for the functioning of a country and of society. Reform must therefore engage high-level policy makers who see water comprehensively and can provide society-wide perspectives.

This is not an impossible task. Outside the water sector, examples exist where country-level strategic planning was aligned around central resource challenges. The 1970s oil crisis spurred a series of concerted actions to reduce dependence on imported oil. For example, Japan took several steps to integrate the problem across its management of the economy, shifting supply focus toward natural gas and nuclear while promoting energy conservation in the industrial, residential, commercial, and transport sectors through a coordinated set of regulatory reforms. More recently, the UK has created the Department of Energy and Climate Change, integrating previously separate government functions to address climate change and energy challenges holistically. For similar reasons, the U.S. Department of Energy has integrated the task of addressing climate change into its overall responsibilities.

Addressing the water gap requires an institutional, cross-sectoral vehicle with enough clout to inform broader economic policy on the basis of a key constrained resource. Policymakers need not wait until water scarcity becomes so severe as to become an emergency. As this report suggests, solutions are available to confront the challenge at reasonable cost, provided an integrated approach is pursued.

Describing the end state: A fact-based approach

The tools presented in this report represent an important step in creating the fact base for a country- or state-level water security vision. Through a process of stakeholder engagement, the supply-demand gap analysis of Chapter 2 and the cost curve and economic analyses of Chapters 3 and 4 can be used to describe a set of scenarios of what the water future of a basin or country may look like. The scenarios can then be used to facilitate a discussion around the trade-offs that countries face. Ideally, the output of such discussions is a shared, quantified vision of how the country can best meet its development objectives in the context of limited water resources. This vision provides the blueprint for the country's future water economy and provides a long term target against which the success of the transformation can be measured. (It is important to note that such an exercise does not imply a "planned economy" approach to solving the water challenge. It says nothing about the instruments and the approaches used to facilitate transformation.)

The previous chapters have shown that a fact-based view of a country's water challenges and solutions is possible with available information. However, we should not understate how rare transparent and precise data is for supply (especially basic hydrological data) and for actual withdrawals from industrial municipal, and agricultural users. Data on groundwater abstraction is particularly difficult to find. Not only is such data not easily available under existing schemes, but data collection and hydrologic observation networks are actually worsening in many countries because of changing national investment priorities and competition for skills[32].

An adequate dataset linking policy choices to financial requirements is an essential starting point in shaping an informed plan to achieve water resource security, and in mobilizing stakeholders to adopt that plan. Investment in the long-term availability of data should be part of any sustainable vision for the water sector of a country.

In countries with severe risk of water scarcity and high economic value at stake, broad-based coalitions should come together and invest in better information systems in the water sector. The coalitions should include representatives from agriculture, finance and industrial ministries in government, water planning commissioners (where they exist), large industrial and agriculture water users, financial institutions, private sector entrepreneurs and key non-governmental experts and academics. In countries with limited resources to manage their water sectors, developing the required dataset should be a high priority for those providing external assistance.

Market design and economic intervention

Once a vision for a water-sustainable economy has been developed, the instruments, institutions and frameworks needed to transition the current economy towards that vision need to be identified.

In many sectors, pricing plays a crucial role in allocating scarce resources to their highest-value use and in mobilizing private sector involvement. There is ample evidence from across the world—from Mexico and Chile to Australia and Spain—that countries with different levels of development and institutional capacity can, when pressed by fiscal or resource constraints, design market mechanisms that achieve a more effective management of water resources. Specific considerations of the design of such mechanisms are beyond the scope of this report, but a few general points can be made:

- **Countries with largely informal water sectors can re-allocate subsidies to incentivize water conservation.** Simply removing subsidies and adjusting pricing might incentivize more prudent use of water, but would also likely put marginal farmers at risk. Market-based mechanisms and well-designed instruments have the potential to overcome such problems, and there is ample experience to draw from.

32 See, for example Water in a Changing World – 3rd United Nations World Water Development Report (WWDR-3) (UNESCO, 2009)

- **Countries with capacity to formalize their water sectors can build on established water rights to institute water-trading mechanisms.** The staged development of Australia's water sector reform shows an example of a path forward. The establishment of water rights and trading mechanisms for the Murray Darling Basin created the price signals needed to incentivize major shifts to high-value crops. This market improved agricultural productivity in Australia by 36 percent from 2000 to 2005, protected and created industries, and developed a large financial water market (worth $1.7 billion in 2007-08).

- **Countries with formal water sectors can align stakeholders around a common water market with formal water pricing regimes.** Certain countries already have formal institutions that are capable of market-based water allocation systems. Such countries have further options, ranging from water banks, where water is sold at "cost-plus" in a clearinghouse of buyers and sellers, to spot markets, where price is set by a market of buyers and sellers who post offers and requests for water on bulletin boards of local irrigation offices or via the internet.

In all of these situations the frameworks of the previous chapters can help point towards some key implications. For example, Chapter 4 showed how reducing energy subsidies or increasing pricing might change the economics of adoption of different measures to close the water supply-demand gap: such policy steps could make water sector investments and water-saving technologies more attractive. The cost curve can help estimate the marginal cost for water under different infrastructure and efficiency measures, therefore informing both tariff design and pricing for water banks. Finally, the cost curve could be used to estimate the size and origin of financial flows associated with water allocation trades, should such mechanisms be adopted.

Institutional transformation

Chapter 4 suggested that a number of barriers could push governments toward adopting the set of levers that is easiest to implement, even if this is much more expensive than the least-cost solution that is, in principle, available. The most easily implementable solution to close the supply-demand gap represents an opportunity cost, which lies in unwieldy institutions that are currently incapable of deploying critical reforms.

In selecting and designing steps to improve institutional performance, the cost curve described in this report can be a useful tool, as it helps assign a financial cost to institutional underperformance. The cost curve can also identify those levers likely to make a big impact but whose implementation is being held back. In a national setting, stakeholders can use this information to help determine the best institutional approach for making transformation of the water sector possible. With a fact-based vision at hand, the process of developing a "color coded" cost curve can identify the biggest obstacles to implementing effective solutions, and may point to the need to strengthen the institutions responsible for water resource management.

Many argue that institutional performance is at the heart of water sector reform[33]. Improved performance management of existing institutions should be an important element of reform, including improving their governance structure and reducing political influence in the management of the organization. As in the case of market-oriented reforms, countries can learn from success stories in many other sectors, from roads and transportation to healthcare.

Mobilizing the private sector

The private sector is critical to the transformation of water use in a country. Chapters 3 and 4 showed that this sector holds many of the solutions and is also subject of many of the trade-offs implicit in achieving a more sustainable water economy.

In developing a plan for transformation, the private sector has at least three important roles to play: as provider of capital, as water user, and as provider of solutions.

Catalyze financial investments from the private sector as a key engine for reform

There are existing technologies and water-efficiency levers that, on paper, look ripe for adoption, yet in many cases end-users cannot mobilize the required capital. Solutions to this problem exist and range from jump-starting traditional investment through public-private partnerships, to utilizing more innovative solutions involving microfinance and direct-lending programs. The capital requirements, sector, and payback time of individual levers can guide decision-makers towards the most appropriate forms of private sector involvement. These include:

- **Public/private water financing facilities:** Private sector investors are not always willing to take on the risks associated with the water sector. It might, however, be possible to reduce this risk by coupling private investment vehicle with "technical assistance" funds

33 See, for example, Water in a Changing World – 3rd United Nations World Water Development Report (WWDR-3),

largely made up of grants or public capital. These funds can take many forms, two of which include venture-capital funds focused on incubating emergent water technologies; and debt and equity funds investing in mid-market and larger companies.

- **Public projects to create the space for private financiers:** In some cases, private financial institutions will not invest until the public sector levels the playing field. In energy efficiency, energy service companies (ESCOs) have lessened the need for upfront investment by providing the needed technology and services in an integrated fashion.

- **Innovative microfinance solutions for the end-user.** Microfinance has been successful in getting low-dollar investments distributed across a fragmented landscape. For certain water-efficiency levers (such as sprinkler irrigation for farmers) microfinance might permit lever adoption where other government and regulation heavy approaches have failed. Microfinance has been useful in assisting the poorest individuals in obtaining access to upfront capital and help support income-generating activities. Identifying those opportunities in the water sector that are ripe for this type of investment where the upfront capital is high but not overwhelmingly so—will be critical to make these investments successful.

In all of these instances, examples from around the world can help design functioning policies to attract private sector capital. Policymakers, financiers, farmers, and the private sector need to cooperate to develop and promote innovative financial tools to ensure those willing to improve their water footprint are given the opportunity—and capital—to do so. Again, a common understanding of the potential and economics of the solutions is a critical first step in building this cooperation.

Incentivize efficiency amongst large water users

Beyond agriculture, other large water users, such as metals, mining, manufacturing and power companies, are coming under pressure to act on water productivity and efficiency. Chapter 4 shows that water-efficiency measures may be available that are financially beneficial to these businesses, yet the managerial resources and incentives may not be in place for them make the necessary adjustments to their operations.

Government policies can help align industrial behavior with the broader objectives of an efficient sector. In the U.S., for example, the Environmental Protection Agency (EPA) works with partner companies to catalogue their greenhouse gas emissions, set reduction goals, and track progress. Partner companies range from large, multinational, Fortune 500 companies with large energy footprints to smaller companies that operate in local areas only. This program has helped companies realize that saving energy is not just a public good—it can contribute to the bottom line. When voluntary programs are not sufficient, mandatory standards can be an alternative, although it is not easy to strike the right balance between fostering changes in an industry versus putting competitiveness at risk with onerous standards or taxes. Successful examples, however, do exist for some sectors of the economy, from building code standards to sectoral approaches such as information provision requirements in energy-consuming equipment.

In many countries, a joint effort will be required to elevate the importance of water productivity, and thus minimize industry's water footprint. Decision-makers should also recognize that what is a business risk, can quickly become a risk to civil society. For example, power generation is exposed to water scarcity, and if preemptive action is not taken to minimize its footprint, consumers may end up paying for additional electricity costs in the future. A fact base on the economics of adoption and on the real potential of efficiency and productivity in such sectors can help identify and prioritize the right regulatory tools for action.

Invest in technology hubs, research and education to unlock future innovations in the water sector

Entrepreneurs and financiers need transparency to benchmark new technologies and understand where innovations can create value. In some cases, water cost curves will be so "steep" that the country is exposed to sharp increases in the marginal cost of water for relatively small changes in demand. In these situations, countries run out of obvious options to tackle the water supply-demand gap, and innovation becomes critical.

The early experience of water innovation hubs suggest that technological innovation is gaining momentum in the water sector. Singapore is becoming a global "Hydro Hub" through a dual approach of governmental support and mobilization of private sector investments, and is establishing a research and development base for environment and water solutions. Singapore aims to increase value-added contribution from the water sector by over 300 percent in less than 12 years, generating roughly 11,000 professional and skilled jobs by 2015. Israel has laid the groundwork for increased investment in water management technologies: its irrigation technology is best-in-class, and there are over 250 businesses that deal specifically with water technologies, exporting $1.4 billion worth of goods in 2008.

It might, in fact, be possible to turn the challenge of making inexpensive technology into an economic opportunity. Countries like China, Brazil, and India have large, educated, and technologically-literate populations that are well equipped to tackle the next challenge. Aligning education, research, policy, and private sector activities around common themes is possible. The Indian IT revolution is a classic case. Innovation in a space like water is ultimately a private-public partnership in which the government sets the rules, supports basic research, and facilitates private sector development and deployment.

* * *

The case for pursuing a revolution in water resources management has never been stronger. We have seen that the challenges that lie ahead are considerable for many countries. But we have also provided evidence that none are insurmountable.

We hope the information presented in this report enriches the global debate and gives policymakers, business executives, and civil society leaders the tools they need to unlock the full potential of water.

Glossary and Abbreviations

Annual capital	Average annual capital requirements for investment and working capital in 2030 to maintain/replace the implemented measures beyond their initial lifetime. Includes two forms of capital: capital for investment (primarily in assets) and working capital to finance operations.
CapEx	Incremental capital expenditure (investment) required for a measure to increase the availability of water resources
Case study countries	Case studies where detailed national supply and demand models and water cost curves were developed: Brazil—State of São Paulo, China, , India, and South Africa
End user	In this report, "End user" refers to the adopters of a measure, i.e. the households, farmers, business or public institutions implementing the measure. "End user" in this context does not refer to consumers.
EPC	Engineering, procurement, construction; refers to the contracting arrangement comprising design of the installation, procurement of necessary materials and construction, either through own labor or by subcontracting part of the work
FAO	Food and Agricultural Organization of the United Nations
GCC	Gulf Cooperation Council, a trade bloc with both economic and social objectives. Member states are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE).
Global supply and demand model	Model covering 154 regions (countries or basins within countries) estimate the magnitude of the gap between water resources demand and supply in 2030 by high-level examination of drivers and constraints. Demand projections, measured in terms of withdrawals, are the water requirements if unconstrained under existing policy regimes, and if it continued at existing levels of water productivity and efficiency. Supply is defined as accessible, sustainable, and reliable supply based on the infrastructure capturing the water resource in place today (taking into account return flows) and additional infrastructure currently planned and completed by 2010. (See Appendix 1: Methodological approaches and assumptions).

GDP	Gross domestic product
GW	Gigawatts, equal to one billion watts, typically used in measuring output of large power plants or power grids
GWP	Global Water Partnership
ha	Hectare (of agricultural land)
IFPRI	International Food Policy Research Institute
IWMI	International Water Management Institute
l/c/d	Liters (of water demand), per capita, per day
MDG	Millennium Development Goals of the United Nations
National supply and demand models	Models developed for case study countries. Methodology follows that of the *Global Supply and Demand Model*, but at a more granular level (See Appendix 1: Methodological approaches and assumptions).
OpEx	Incremental operating cost required for the measure compared to business-as-usual. Includes incremental operational and maintenance costs and incremental savings (e.g., from reduced cost for water treatment and distribution, and reduced energy consumption).
m^3	Cubic meter of water
Measure	Approach to increasing the availability of water resources compared to today's water intensity of demand and currently available supply. Comprises both making demand more efficient in agriculture (e.g., drip irrigation), industry, and municipal uses as well as making additional sources of supply available (e.g., new dams and desalination). Focus in this research has been on the most relevant measures in each geography and technologies that are available today.
Payback curve	Model to evaluate the returns that any given measure would generate against the capital needed to fund it as perceived by the end user or adopter of a measure, based on the water cost curve of the given country or basin

Sectors	Measures comprise three demand and one supply sectors: - **Agricultural demand**: Water use for irrigation, taking into account existing use of precipitation for rain-fed agriculture - **Industrial demand**: Water use in all industrial processes, e.g. cooling and washing - **Municipal and domestic demand**: Demand for commercial water use, domestic consumption, and public municipal use (e.g., public landscaping, fire departments, etc.) - **Supply**: All forms of making available water resources at a sufficient quality for its lowest-quality use (agriculture); includes groundwater, surface water, non-conventional sources such as desalination, and water reuse
SIWI	Stockholm International Water Institute
Supply-demand gap	Imputed deficit in 2030 between water demand and supply, as shown in the national and global water supply and demand models
UGRHI	Unidade de Gerenciamento de Recursos Hídricos; Brazilian water resources management unit
Water cost curve	Micro-economic model to assess of the potential and cost of a set of measures to close the projected deficit between water supply and demand in a given country or basin
Water productivity	Amount of consumptive water use per unit of output (or area, e.g., for landscaping)
WMA	Water Management Area (South Africa), one of 19 distinct management units under the South Africa National Water Resource Strategy
WWC	World Water Council
$ or USD	Real 2005 US Dollars

Appendix 1
Methodological approaches and assumptions

Given the importance of representing water resource budgets specific to each basin and region, the main body of the report has sought to provide a reasonably comprehensive explanation of the methodology for key analyses such as supply, demand, and the water-marginal cost curve. The boxes in the main body of the report offer explanation of specific methodological concepts and choices.

Methodological concept	Discussion in report body
Water sector definitions and scope of this report	**Box 1**—Reconciling different definitions of the "water sector"
Water supply and demand definitions	**Box 2**—How should water demand and supply be defined?
Water quality and reliability definitions	**Box 4**—Different water for different purposes
Cost curve methodology	**Box 5**—Assessing the cost of delivering water—the cost curve for incremental water availability
Water demand for irrigation versus rain-fed agriculture	**Box 6**—Measuring "blue water", accounting for "green water"
End-user payback curve methodology	**Box 7**—The payback curve

This appendix provides further detail on the key assumptions, approaches, inputs and limitations, for four main aspects of the analyses presented in this report:

- General supply and demand methodology—global application (***Chapter 2)***
- Supply and demand methodology—regional and country applications (***Chapter 2***)
- Selecting and assessing technical measures to close the supply-demand gap (***Chapter 3***)
- Translation of the cost curve into an end-user payback perspective (***Chapter 4***)

General supply and demand methodology—global application (Chapter 2)

An overview of the supply and demand definitions of this report is given in *Box 2—How should water demand and supply be defined?* Additional aspects of the methodology are highlighted below.

The report's emphasis is on the analyses of water resources' supply and demand at the regional level, supported by detailed basin-by-basin estimates of supply and demand and cost curves of measures that have the potential to narrow the supply-demand gap. However, to understand and quantify the supply-demand situation of regions and countries at a high level, we also developed a methodology to assess the respective gaps using global datasets. Our global supply and demand projections, which we applied to a total of 154 regions, are developed in a model that aligns roughly with the regions used by the International Food Policy and Research Institute (IFPRI). As such, our model uses 115 core economic units (countries or aggregated countries), zooming in for basin-level detail in China (14 basins), India (14 basins) and the United States (14 basins).

Total demand is the sum of initial withdrawals in the municipal/domestic, industrial , and agricultural sectors . We focus on these sectors which require consumptive use for productive activity. In-stream water requirements for hydropower are not included, and to the extent hydropower use precludes other productive use, such quantities are deducted from the "accessible, reliable supply" definition. Usable return flows from these withdrawals (water that returns to river courses and groundwater in a manner permitting future use) are also accounted for in the definition of water supply. Similarly, environmental requirements are also accounted for in our definition of water supply in our methodology by reducing available "supply" by an appropriate amount.

Agricultural water demand. Projected irrigation withdrawals are calculated based upon total demand for irrigated production (metric tons) and water productivity parameters (yields for rain-fed and irrigated area and withdrawal-to-field ratios), as detailed below. We based our region-by-region projections of total crop production on widely accepted basecase production estimates from IFPRI, which makes estimates for 19 crops of global agricultural demand under land, technology, and water constraints. Included in the IFPRI crop projections are validated assumptions of changing diets within core countries. Rain-fed and irrigated yields for each crop and region in our base year of 2005 are based on IFPRI aggregations of various data sources:[34]

- **Baseline demand for irrigated production.** Based on IFPRI projections, we calculated irrigated production per crop as follows: Irrigated production = total domestic demand + net exports—rain-fed production
- **Rain-fed production.** Projected rain-fed production was calculated by multiplying external projections of rain-fed cropping area with current yields.
- **Irrigation withdrawals.** Irrigation withdrawals were determined by first calculating irrigated area per crop by dividing total irrigated production by irrigated yields. In a second step, we multiplied the imputed total irrigated area with withdrawals per hectare of irrigated lands. For the latter, we started with monthly crop water requirements and used external estimates of efficiency multipliers for different types of water sources, geographies and crop, to arrive at the quantity actually withdrawn from a primary source.

Non-agricultural water demand (for industrial and domestic use). We based non-agricultural water withdrawals upon projections of the key growth drivers population and GDP, and while maintaining water productivity at 2005 levels.

Surface water supply. Our estimates for regional supply are built upon projections from assessments by IFPRI IMPACT-WATER[35], which uses representative reservoir models, data on historical surface water flows and surface-water variability, and the ability of infrastructure to meet water demand. Their results also explicitly consider the temporal aspects of demand (through monthly crop water requirements and precipitation contributions). They also respect spatial demand patterns which constrain how much of the captured water resource can be supplied to the demand patterns. Where the regions modeled were countries, the constraints also represented the distribution constraints given multiple basins within a country (water sharing agreements between countries also constrain the amount of supply).

One significant build-on to the IFPRI work was to generate a measure of reliability to the water supply estimates. Using hydrological data aggregated by IFPRI, we used historical patterns of climate variability in each basin in order to determine the reliability to which the basin infrastructure could deliver surface water supply. We then established a base-case 2005 supply number through a basin-by-basin regression analysis on given renewable surface water, reservoir capacity and infrastructure constraints.

Groundwater supply. For groundwater supply, we used the minimum of installed pumping capacity or the renewable groundwater total for each region.

34 See *World Water and Food to 2025* (International Food Policy and Research Institute) for full description
35 IFPRI IMPACT-WATER model is designed to examine alternative futures for global food supply, demand, trade, prices, and food security, coupling agricultural and trade models with assessment sof agricultural water demand and reservoir models for supply.

Supply and demand methodology—regional and country applications (Chapter 2)

The methodology of regional supply and demand models broadly follows the logic described above for the global supply and demand model. In order to obtain a more detailed picture, country case study analyses were further disaggregated into basin-level assessments of supply and demand as follows: India 19 major catchment areas and basins, China 10 basins, Brazil—São Paulo 22 water management areas, and South Africa 19 water management areas.

Deviations from the global supply and demand methodology and case study specifics are outlined below:

Agricultural water demand. We calculated agricultural demand in terms of irrigation withdrawals for some 12-14 crops per region, following the methodology applied in our global supply and demand analyses.

Domestic water demand. To project domestic withdrawals in each case study, we used the best available external population projections for each of the regions by basin. We segmented these basin-level population projections into six socioeconomic groups for 2005 and 2030 to incorporate the effects of growing affluence. These groups differentiate low-income, middle-income, and high-income users, based on average country income, and whether they live in urban or rural areas. For each group, we assumed a different level of per-capita domestic water consumption. Water use at the household level does not fully reflect the abstraction needed as some of the water is leaked in delivery. We added these system losses between primary abstraction and the user level of domestic water demand in order to represent the full withdrawals at a basin level, and allow such system losses to be addressed via the cost curve.

Industrial water demand.[36] For each case study, we projected baseline withdrawals for each major industry segment by tying these to increases in the underlying production (for example, tons of mined ore or MWh of power generated). For each segment, we made water withdrawal projections based on this increase in production and considering constant water productivity (volume of water withdrawals per unit of production). Where changes in technology are mandated, we included the resulting water productivity improvements in the baseline. This was the case for power generation in South Africa, for example, where all new generation capacity is required to use dry cooling technology. Where productivity data was poor, we grouped industry segments and projected growth in the remaining industrial water withdrawals according to GDP growth, while keeping water withdrawal per unit of GDP constant.

Other demand. In some areas (South Africa, for example) significant modification of catchments through agro-forestry will improve utilization of "green water" precipitation but with a corresponding impact on the "blue water" supply available through existing infrastructure. We accounted for such an impact on future supply via the demand calculations.

36 Industrial demand includes both direct withdrawals from the environment (e.g. power generation) and water provided through municipal systems. Demand for the "commercial" sector was generally included in industrial demand. In São Paolo, commercial demand was incorporated as part of municipal demand.

Selecting and assessing technical measures to close the supply-demand gap (Chapter 3)

It is worth detailing several key assumptions and approaches in the selection and assessment of measures to close the supply-demand gap. (An overview of the cost curve methodology is presented in *Box 5—Assessing the cost of delivering water—the cost curve for incremental water availability*. For a full list of all measures evaluated in the case study countries, see Appendix B.)

Measure selection for case studies

The measures identified in each case study country were compiled together with local experts and emphasize the highest potential opportunities available to close the gap. (While the aim was to develop a comprehensive list of *all* significant measures available to close the supply-demand gap in each country, these lists are not necessarily exhaustive.) The measure set selected in each case study country reflects its particular water usage profile. In India, where water demand is dominated by agriculture, emphasis was placed on improvement potential in agriculture. In South Africa and Brazil, industrial measures, focusing on the most relevant sectors of the region—for example, mining and power generation in South Africa—play a much bigger role, as do municipal efficiency measures.

Volume impacts of measures

Overall, the net impact of each measure depends on two major sets of assumptions: (1) the overall technical applicability of the measure and (2) the consequent physical impacts of the full technical implementation of each measure.

First, from an applicability standpoint, our approach estimates a maximum technical potential for each measure, with the applicability to a set of water-using activities unconstrained by the "likely" adoption of the measure. The cost curve then becomes a starting point for discussions on steps needed to capture this full potential. For example, we estimate what fraction of projected pulp and paper production, steel production, or power generation could use a particular technology. The estimates for technical applicability are most nuanced in the agricultural arena, where we closely examined the incremental area of production for each crop where the measure could be implemented.

Next, our approach then translates the technical applicability into a full technical potential. The physical impact of each measure is calculated based on a status-quo background of a pattern of withdrawals and return flow from those withdrawals. The potential per individual measure (for example, drip irrigation on one hectare of land) therefore depends on the specific geography and the current pattern of water use and water productivity. Accordingly, similar measures may have significantly different potential in different countries, and even between different basins. The savings potential of drip irrigation, for example, critically depends on the status quo of irrigation in the specific geography. The savings potential is much greater where flood irrigation is currently used, compared to where irrigation systems are already using more advanced technologies such as sprinkler irrigation. The impact on water availability assumed for each measure in our cost curve models has been derived by country and basin from scientific research and based on interviews with experts and practitioners in the respective field.

The net impact on water availability of a measure by definition affects both the withdrawals but also the return flows—an important consideration, as other users may be dependent upon the return flows as a portion of their supply. This makes some measures more complicated than others to estimate. Drip irrigation is a case in point. At a farm level, drip irrigation can have massive efficiencies in withdrawals if the same production is maintained. But at an aggregate river basin level the impact could be different: by reducing return flows, this measure could actually reduce the supply available to others currently dependent on these flows and therefore diminish the true aggregate impact on closing the gap.

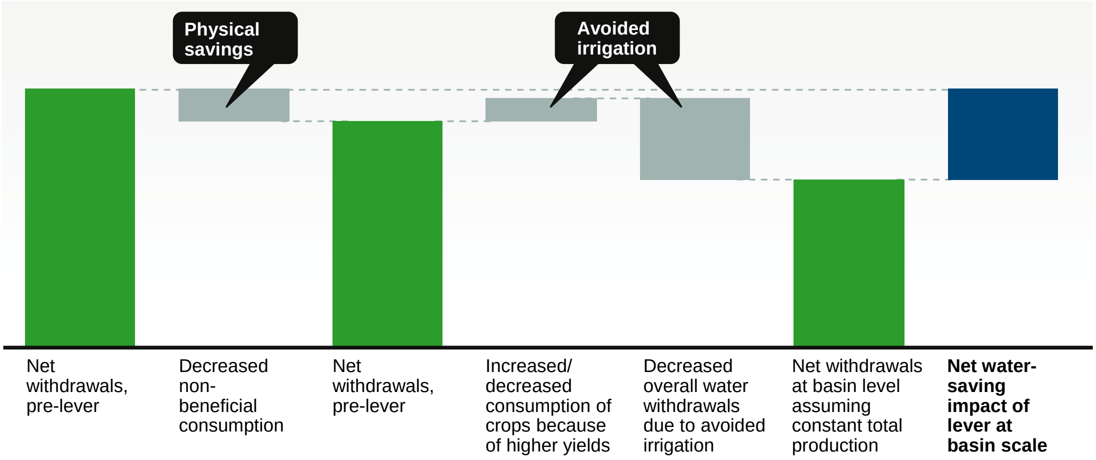
For **agricultural measures**, the net impact on water availability is based on two concepts: Part of its impact will come because of increased productivity and hence *virtual water savings*, and part because of *physical water savings*:

- **Yield improvements ("virtual" water savings).** Under the assumption that aggregate demand for crop output remains constant, and increase in crop yield per hectare—both on irrigated and rain-fed land (i.e. "blue" and "green water")—results in a decrease of the total area cultivated in a country to produce the desired output. Yield improvements on one field therefore offset production on another field, so that the productivity gains in crop production offset water use elsewhere and increase water availability to other water uses in that basin. The net impact of avoided irrigation is the difference between the irrigation need of the replaced production and the increase in water consumption needed to sustain the yield increase, as shown in Exhibit A-1.

Exhibit A-1

Effect of physical water savings and avoided irrigation on net water withdrawals

CONCEPTUAL



SOURCE: 2030 Water Resources Group

- **Physical water savings**. The second option is to reduce water consumption at constant crop yields, and thus make that water available for alternative uses elsewhere. This is the case in shifts to more water-efficient irrigation techniques (e.g. from flood to sprinkler or drip irrigation).

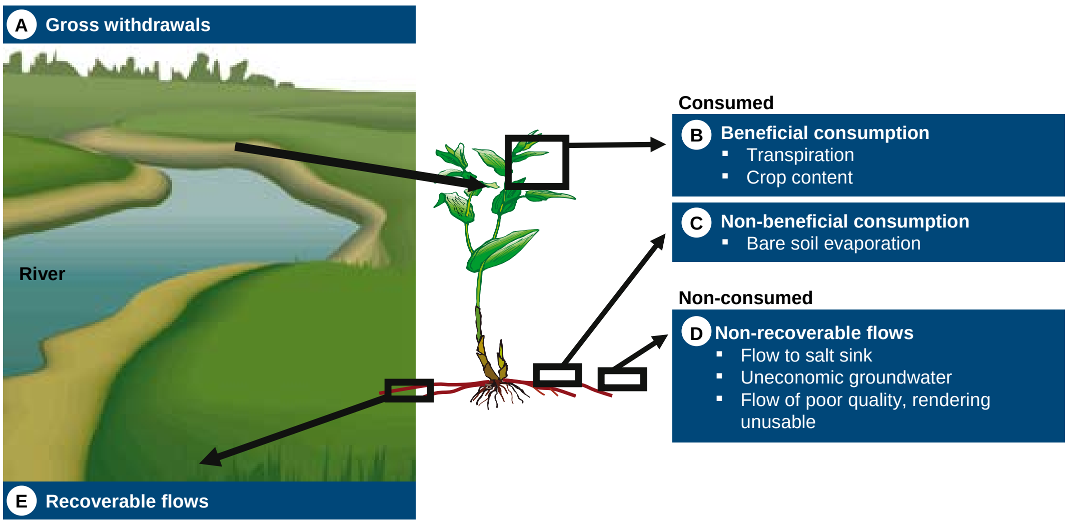
In many cases, the measures we have identified combine both concepts ("more crop per drop"); they have a water-saving component ("less drop") to them, but also increased yields ("more crop"). Their net impact as shown in the cost curve is therefore the aggregate benefit achieved from both concepts together (Exhibit A-1).

For both types of water savings potential, we have ensured that the measures' impact only assesses the conservation of water that was truly "wasted"and can be recovered by implementing the measure. Simply growing more on the same area is not enough, for this may actually require more water. Similarly, stopping the "wasted" flow that is actually recaptured by others as supply is simply "robbing Peter to pay Paul".

Instead, for agricultural use, the recovered "wasted" water needs to come from either reduction in non-beneficial consumption, i.e. avoidable evaporative losses, or from the existing 'non-recoverable fraction', i.e. water that flows to inaccessible locations of or impaired quality. The net hydrological impact of each measure is therefore the sum of its potential to reduce non-beneficial consumption (C in Exhibits A-2 and A-3) and non-recoverable flows (D).

Exhibit A-2

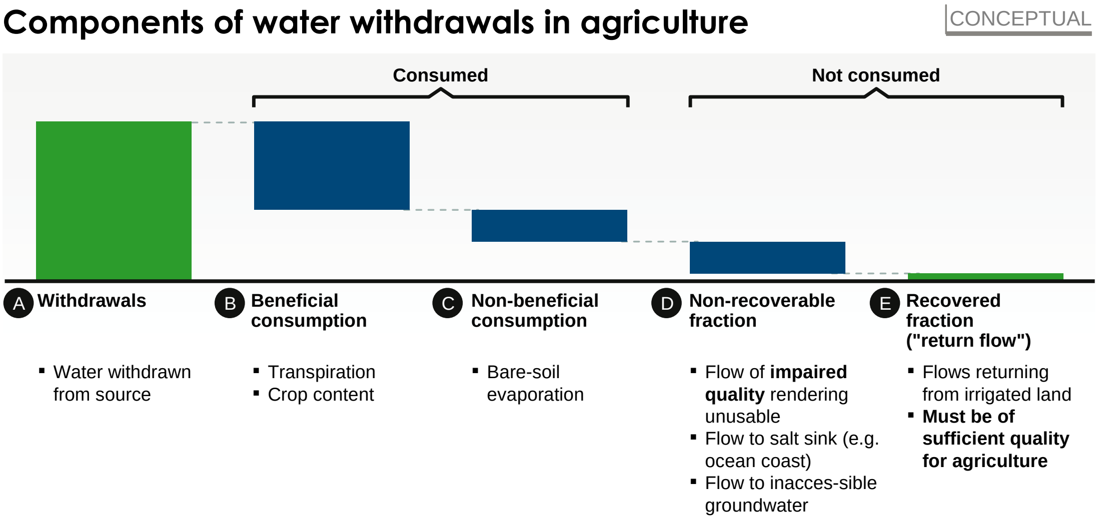
Illustrative overview of components of water withdrawals in agriculture



SOURCE: 2030 Water Resources Group

Exhibit A-3

Components of water withdrawals in agriculture



SOURCE: Expert interviews; Perry, Steduto, et al., *Increasing productivity in irrigated agriculture: Agronomic constraints and hydrological realities,* 2009; 2030 Water Resources Group

Effect of implementation order of measures

The cost curve applies measures in the order of their net cost from lowest (i.e. measures with a net benefit) to highest to fill the gap. For each measure, its full potential in the geography is used before the next measure is picked.

Some measures interact, i.e. the adoption of one measure changes the potential of another. For example, once losses from municipal leakage have been reduced, the impact of installing water-efficient appliances is somewhat lower because the amount of water lost between abstraction and use for each liter of water consumed has already been reduced. We implemented this "order of implementation" effect by use of a multiplier value between 0 and 1 that is applied to a measure when another measure with such an interaction comes earlier in a cost-curve solution.

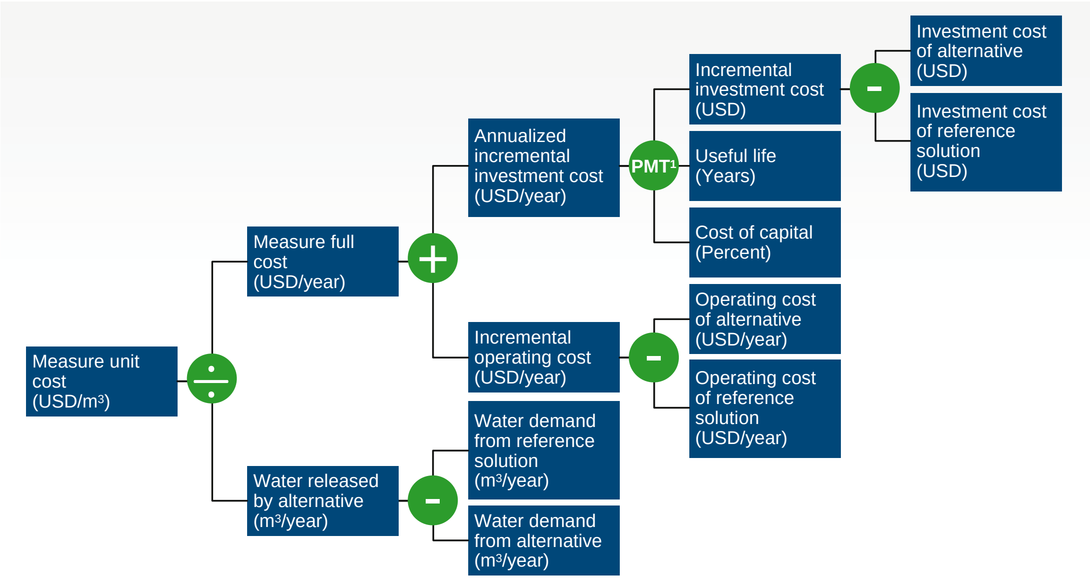
Unit cost of measures

Measure costs are defined as the incremental cost of a water-efficient demand technology or supply-side measure, compared to business as usual, measured as ($/m^3)of water made available, which is the net between water withdrawals and return flow. Measure cost represents the pure "project cost" to install and operate the measure. Capital availability is not considered a constraint.

Demand measure costs are calculated according to the formula in Exhibit A-4. The full cost of a water-efficient demand measure incorporates investment costs, operating costs, and possible cost savings generated by use of the alternative measure (e.g., cost savings for water pumping, treatment and distribution). Similarly, the full cost of an additional supply measure comprises investment cost and full operating costs for the measure. The full cost does not include transaction costs, communication/information costs, subsidies, taxes, or the consequential impact on the economy (e.g., advantages from technology leadership or a loss of jobs).

Exhibit A-4

Cost formula for demand measures



1 Calculates the payment for a loan based on constant payments and a constant interest rate
SOURCE: 2030 Water Resource Group

Investment cost or capital expenditure is accounted for as annualized repayments of a loan. The repayment period is the functional lifetime of the equipment. The interest rate used is a long-term government bond rate of 6 percent for supply, and private sector interest rates of between 12-14 percent for demand-side measures, depending on the case study country.[37] Net operating expenditure, including personnel, material, energy, and maintenance cost, and savings, is assessed as a real amount to be expensed each year.

The cost curve takes an integrated, societal perspective instead of that of a specific end user, i.e. it illustrates cost requirements to society. Therefore, redistributional effects of taxes and subsidies within an economy are not reflected in the full cost of measures.

37 11.9 percent in Brazil; 12 percent in India for industrial and municipal/domestic measures, 8 percent for agriculture; 14 percent in South Africa

All costs in the model are based on current costs and estimated projections, presented in real 2007 U.S. dollars. Estimates are based on best available projection methods, such as models (if available), expert views, and educated extrapolation. Given the long time horizon of more than 20 years, a certain estimation error is inherent in the approach. Therefore, the cost curve should be used for overall comparisons of the size and cost of different opportunities, the relative importance of different sectors, and the overall potential to close the gap in the different basins, rather than for predictions of the development of individual technologies.

Transactions costs—costs incurred in making an economic exchange above and beyond the technical project cost (e.g., education and enforcement costs)—are not included in the cost curve. Similarly, information campaigns and training programs that are required for implementation of a measure are considered transactions costs and are not included in the cost curve.

Aggregation of results at the national level

Establishing a solution at basin-level only. The optimization addresses each basin individually. This means that each basin gap is closed with the set of measures available locally, depending on local consumption patterns. Accordingly, measures are utilized to their full potential only in basins where they form part of the basin's least-cost solution to close the gap. That share of the aggregate, national measure potential located in basins where either imputed demand is lower than supply, or where lower-cost alternatives are available in sufficient quantities to close the gap, is not utilized. The cost curve at the national level then reflects the sum of all individual basin-level cost curves.

Basins with more abundant water resources can help more water-scarce basins only based on pre-existing or new water transfer schemes, under the basin-level optimization. As presented in Chapter 3, such schemes form an important contribution to closing the gaps in South Africa and São Paulo.

Establishing a solution across basins. At the national level, each measure is utilized to the full sum of its potential in each basin. This second optimization does not take into account whether the measure being adopted already exists at all, or whether it has already been filled with less-expensive measures. This approach follows the assumption that a country's overarching goal is to close the gap at the least cost. Accordingly, water is released wherever it is least expensive to do so. This implies that economic activity might have to shift from basins where it is expensive to release additional water to locations where water can be made available more cost-effectively. This cost, however, has not been taken into account when analyzing lever cost.

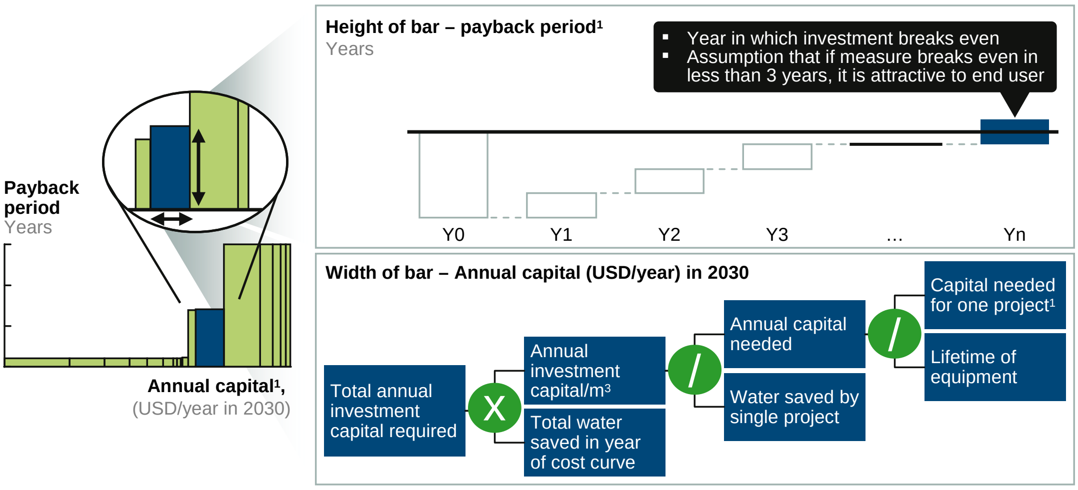
Approach to calculating payback times and annual capital (Chapter 4)

An overview of the payback curve, its methodology and use are presented in *Box 7—The payback curve* in the main section of this report. The methodology for calculating the values on the vertical and horizontal axes of the payback curve is outlined below.

Exhibit A-5

Project payback curve and methodology

CONCEPTUAL



1 Not including interest/financing cost
SOURCE: 2030 Water Resources Group

Annual capital—the horizontal axis

The horizontal axis of the payback curve shows the aggregate annual capital requirements in 2030 in real 2007 U.S. dollars. Annual capital represents the average amount of capital required after 2030 to renew the asset base of a measure after its useful life. Two forms of capital are included in the calculation: capital for investment (primarily in assets) and an approximation of working capital to finance operations.

Capital for investment is calculated as the upfront capital required for one project divided by its useful life and the water made available per project, then multiplied by the total water made available by the measure in the year of the cost curve. In effect, this equals the annual straight-line depreciation value of all the physical assets required to deliver the total water made available by the measure.

The approximation for **working capital** concentrates on agricultural levers that depend on the upfront financing of consumables, such as fertilizer, agrochemicals, and seeds. For the purposes of the payback curve, one year's worth of the incremental needs for fertilizer, agrochemicals, and seeds have been treated as annual capital. As working capital changes are otherwise dependent on detailed company or business case information, they have not been considered unless explicitly available in measure cost data.

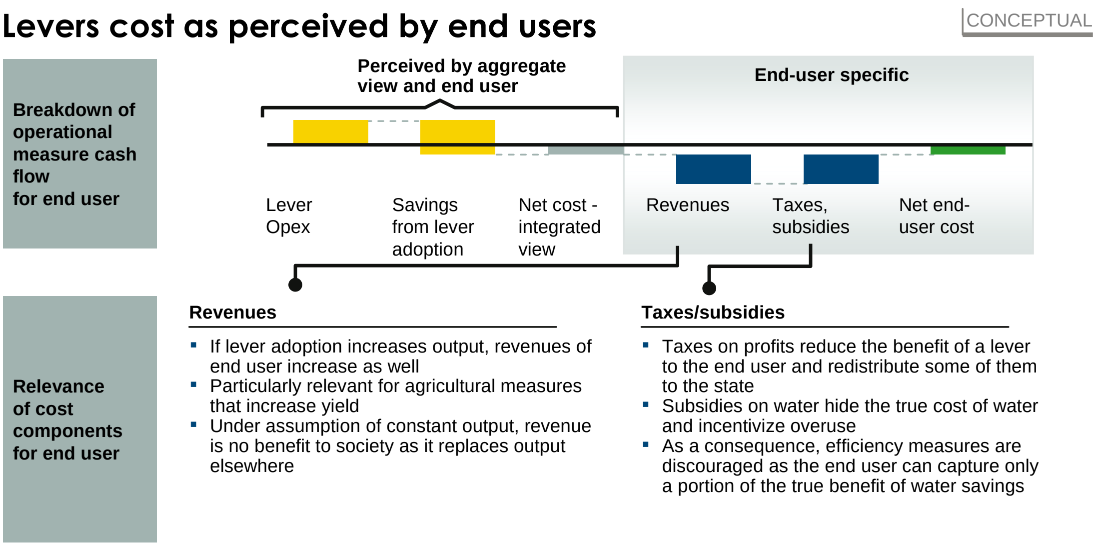
The payback period—the vertical axis

The vertical axis shows the payback period of the project, i.e. the year in which the project repays the amount of the initial upfront investment. The initial capital outlay is formed by the investment cost for acquiring the physical assets related to the lever, e.g. the pipes, pumps, and valves for a drip irrigation system. The upfront investment does not include any financing costs. The annual cash flows generated by the adoption of a measure are calculated from the perspective of the end user, or adopter of the measure, as shown in Exhibit A-6. It comprises incremental revenues and net incremental operating expenditure, which include savings from the adoption of the measure, taxes paid by the end user, and subsidies that may either increase or decrease the net cash flow from the measure. Subsidies increase the net cash flow if they are granted for adoption of the measure, e.g., subsidies on drip irrigation systems. They decrease the net cash flow if they are granted on an input that is saved by the measure, e.g. subsidies on water or fertilizer, if the use of fertilizer is reduced by the measure.

Measures that never break even, either because they do not generate positive cash flows or because their cash flows are insufficient to cover the upfront investment during the useful life of the asset, are included with a payback time "> 10 years" on the payback curve. Payback times of one year or less are summarized as "~1 year" on the curve.

Exhibit A-6

Levers cost as perceived by end users



SOURCE: 2030 Water Resources Group

Appendix 2
List of measures assessed in country case studies

This appendix lists the measures assessed in the country case studies, all of which are based upon existing technologies. For each measure or group of measure we provide a brief description, indicate the countries[38] for which that measure was assessed, and describe the key assumptions underlying our calculations on both volume of water released and on cost. We highlight here the most salient of the assumptions used as representative of a much longer list, all of which are informed by many interviews and external publications. For many of the assumptions, the uncertainty is considerable given the long time-lines involved; the numbers cited here are the midpoint estimates used in our models

The descriptions of agricultural demand measures is best understood in the context of our methodology (see Appendix 1). The potential of each measure is based on a reference case that reflects the pre-existing conditions in case study countries today. As a result, identical measures can have different incremental improvements on efficiency depending upon respective geography. This is especially apparent for agricultural measures, where the impact on water availability, and thus the unit cost *on a water volume basis*, is strongly dependent upon the yield gain potential in the crop/geography segments. As the impact of these measures will differ considerable by crop and basin; we show here the weighted averages across all crops and basins within each deep-dive country. The figures shown on the cost curve, however, do not use an aggregate assumption but are rather the sum of all the impacts of each lever for each geography and crop. Also, we acknowledge that some of these measures interact with each other and are not entirely additive. As noted in the methodology section, we adjust the for these interactions in the impact of the most significant of these measures, while not attempting to represent all potential interactions

Finally, the subdivision of some agriculture measures into “rainfed” and “irrigated” reflects the different yield gains that each measure may have in the respective land in the particular geographies. In such cases, we assume the prevailing irrigation types in the respective basins.

38 BRA = Brazil, State of São Paulo, CHN = China, IND = India, RSA = South Africa

Agricultural demand measures

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Agricultural rainwater harvesting with fertigation	Boost productivity of currently rain-fed crops by applying water during dry spells; requires construction of small reservoirs for rainwater collection	CHN IND RSA	• Applicable to all crops, mainly in mountain areas in CHN • Yield improvement 10% (RSA) -40% (IND and CHN) • 20 Mha capacity in total by 2030 in IND; RSA: assumes 5% current adoption, increasing to 10% by 2030 (most subsistence farms, and some commercial land), from 2-10% in CHN	▪ CapEx 240-280 $/ha ▪ 10-20 $/ha OpEx increase, mainly additional repairs
Canal lining	Line on-farm canals with cement/plastic to reduce seepage	CHN IND RSA	▪ Applicable crops: oil crops, vegetables, roots and tubers, sugarcane, fruits, cotton ▪ No yield improvement; gross water savings 3% ▪ Potential area: an incremental 9% of farmers in RSA, 10% of total crop area in IND (mostly dry areas)	▪ Fertilizer, fuel and electricity savings ▪ OpEx savings 6 $/ha in RSA, 25 ▪ Upfront CapEx/ha: $270 in IND, RSA; ~$500 in CHN for applying anti-seepage materials
Channel control	Introduce more active controls to limit spill losses through automated measurement of flows and better timing and scheduling of irrigation flows	RSA	▪ No yield improvement; gross water savings 10% ▪ Potential: incremental 60% of irrigation areas	▪ CapEx 40 $/ha ▪ OpEx savings of $35,000 p.a. over 16,000 ha; reduces supervisory need for staff
Drainage construction (irrigated)	Construction of adequate drainage structures will increase yield and reduce need for irrigation	IND RSA	▪ Yield improvement and gross water savings 10%-30% ▪ Conservatively estimated to help additional 1% of maize farmers in RSA, 9% of total crop area (9.5 Mha) by 2030 (all waterlogged area) in IND	▪ CapEx 240-280 $/ha ▪ Labor and operational repairs decrease by 8 $/ha in RSA, 102 $/ha in IND (for fuel savings)

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Drainage construction (rain-fed)	Construction of adequate drainage structures will increase yield and enable cultivation of land during monsoon	IND	▪ Yield improvement 100% (only applicable to currently fallow land) ▪ Potential 2% of total crop area (2.1 Mha, allowing cropland currently unusable during monsoon to be cultivated)	▪ CapEx 60 $/ha ▪ Labor and operational repairs decrease by 20 $/ha
Drip irrigation	Applying water through low-pressure tubing requires less water than flooding	BRA CHN IND RSA	▪ Applicable to oil crops, vegetables, roots and tubers, sugarcane, fruits, cotton, coffee; only cash crops in CHN ▪ Gross water savings 20-60% ▪ Yield improvement 25-30%, assumes fertigation as part of system; 15% in CHN ▪ Potential 25-70% of total crop area	▪ Reduced cost for fertilizer, labor, fuel, electricity and pest control; increases for repairs, and interest on capital ~150-250 $/ha ▪ ~1,000 $/ha CapEx in IND, CHN; 3,500 -4,000 $/ha in RSA, BRA
Genetic crop development (irrigated)	Continued development and adoption of varieties that enable farmers to attain higher yields; includes both conventional breeding and genetic engineering	BRA CHN IND RSA	▪ Applicable crops: wheat, maize, oilseeds, vegetable, cotton, sugarcane (by 2020); all in CHN ▪ Yield improvement typically 1-2% p.a., based on historical improvements 5% p.a. in CHN ▪ Potential 80-90% of area	▪ Seed premium of 50% in BRA, RSA, 13-29 $/ha in IND
Genetic crop development (rain-fed)	Continued development and adoption of varieties that enable farmers to attain higher yields; includes both conventional breeding and genetic engineering	BRA CHN IND RSA	▪ Applicable crops: wheat, maize, oilseeds, vegetable, cotton, sugarcane (by 2020); all in CHN ▪ Yield improvement typically 1-2% p.a., based on historical improvements, 5% p.a. in CHN ▪ Potential 65-95% of area	▪ Seed premium of 50% in BRA, RSA, 13-29 $/ha in IND

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Improved fertilizer balance (irrigated)	Apply optimal mineral balance to improve mineral absorption and sufficiently supply micro-nutrients	CHN IND	▪ Yield improvement 7% in IND; 15% in CHN ▪ Potential 80% of total crop area in IND by 2030, 70% in CHN	▪ Reduction in N offsets increase in P and K ▪ OpEx savings of 8 $/ha in IND ▪ Cost of 0.05 $/m³ in CHN
Improved fertilizer balance (rain-fed)	Apply optimal mineral balance to improve mineral absorption and sufficiently supply micro-nutrients	CHN IND	▪ Yield improvement 7% in IND; 15% in CHN ▪ Potential 80% of total crop area in IND by 2030, 60% in CHN	▪ Reduction in N offsets increase in P and K ▪ OpEx savings of 4 $/ha in IND ▪ Cost of 0.12 $/ m³ in CHN
Improved germplasm (irrigated)	Increase average yield potential by dissemination of existing, higher-yielding seed varieties that are best adapted to the specific, regional conditions; applied to irrigated lands	BRA IND RSA	▪ Yield improvement 10% in RSA, 20-30% in IND, 30-40% in BRA ▪ Potential 95% of area in 2030 (50% of subsistence farmers) in RSA, 80% in India, 85-100% in BRA	▪ Crop-dependent seed premium, 6-50 $/ha
Improved germplasm (rain-fed)	Increase average yield potential by dissemination of existing, higher-yielding seed varieties that are best adapted to the specific, regional conditions; applied to rainfed lands	BRA IND RSA	▪ Yield improvement 10% in RSA, 20-30% in IND, 30-40% in BRA ▪ Potential 95% of area in 2030 (50% of subsistence farmers) in RSA, 65% in India, 85-100% in BRA	▪ Crop-dependent seed premium, 6-50 $/ha
Increased fertilizer use (irrigated)	Increase fertilizer use to reduce mineral exhaustion and increase yields; applied to irrigated lands	IND RSA	▪ Yield improvement 50% (only implemented on subsistence farms) in RSA, 19% in IND ▪ Potential area assumed to be 95% already in RSA, increasing to 100%	▪ Assumes fertilizer cost increase ▪ 120 $/ha in RSA, 62 $/ha in IND

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Integrated plant stress management (irrigated)	Efforts to improve yield by resistance to abiotic (climate) and biotic (pests, disease) stresses. Combine impact of improved practices (such as integrated pest management) and innovative crop protection technologies	BRA CHN IND RSA	▪ Yield increase 5-20% in BRA, RSA; 10% in CHN; 10-35% in IND ▪ Potential area 9-30% in RSA, 50% in CHN; 90% in IND, 60-100% in BRA	▪ Pest and weed control costs increase ▪ Crop, country dependent 8-100 $/ha
Integrated plant stress management (rain-fed)	Efforts to improve yield by resistance to abiotic (climate) and biotic (pests, disease) stresses. Combine impact of improved practices (such as integrated pest management) and innovative crop protection technologies	BRA CHN IND RSA	▪ Not applicable to rice, vegetables in CHN ▪ Yield increase 5-20% in BRA, RSA; 10-35% in IND; 10% in CHN ▪ Potential area 9-30% in RSA, 55% in CHN, 60-80% in IND, 60-100% in BRA	▪ Pest and weed control costs increase ▪ Crop, country dependent 8-100 $/ha
Irrigation scheduling	Prevent farmers from over-irrigating; linked to controls/subsidies for groundwater pumping in IND	BRA CHN IND RSA	▪ Yield improvement 5-20% ▪ Gross water savings 12% ▪ Currently 40% of potential area to 95% in RSA; 33% of furrow irrigated land in BRA; 50% of groundwater irrigated area in IND; potential 28% of total irrigated area by 2030; in CHN, from 0% today to 5% (grains) and 10% (cash crops)	▪ Fertilizer, fuel and electricity savings; cost for informative device on soil moisture level ▪ Savings crop, country dependent 20-80 $/ha
Mulching	Cover soil with protective plastics to prevent water evaporation and keep temperature constant	CHN	▪ Applicable to all type of crops ▪ Yield improvement 10% ▪ Currently applied to 5% of crops, increases to 70% by 2030	▪ Equipment to apply film on the field ~0.01 $/m³ ▪ OpEx ~0.14 $/m³ mostly plastics film replacement cost

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Piped water conveyance	Use of pipe system to transport water and reduce water evaporation	CHN	▪ Applicable to all crops ▪ Strong presence in Hai and Huang basins ▪ No yield improvement ▪ Potential 10% today; increases to 40% by 2030	▪ Upfront CapEx for laying pipes ~1,000 $/ha ▪ Reduced energy and labor cost to maintain channels ~0.12 $/m³
Precision farming (irrigated)	Use of GPS to optimize sowing density, fertilizer and other input needs	BRA RSA	▪ Applicable to all annuals, limited and variable in fruits, tree-crops in RSA, all crops in BRA ▪ Yield improvement 10-15% ▪ Potential: assumed to be 15% today, increases to 80% by 2030 in RSA, in BRA from 13% today to 30%	▪ Fertilizer costs increase by half of projected yield increase, and labor costs increase due to skill required ▪ CapEx of 310 $/ha in RSA, 600 $/ha in BRA for tractor and spreader
Precision farming (rain-fed)	Use of GPS to optimize sowing density, fertilizer and other input needs	BRA RSA	▪ Applicable to all annuals, variable application limited in fruits, tree-crops in RSA, all crops in BRA ▪ Yield improvement 10-15% ▪ Potential: assumed to be 15% today, increases to 80% by 2030 in RSA, in BRA from 13% today to 30%	▪ Fertilizer costs increase by half of projected yield increase, and labor costs increase due to skill required ▪ CapEx of 310 $/ha in RSA, 600 $/ha in BRA for tractor and spreader
Pre-harvest treatment	Prevent post-harvest crop losses through treatment of fruits, vegetables, and high-value crops prior to harvest	IND	▪ Potential loss reduction of 5%	▪ Cost benchmarked off "reduction of transport losses"
Post-harvest treatment	Prevent post-harvest crop losses through washing and chemical post-harvest treatments	IND	▪ Potential loss reduction of 2.5%	▪ Cost benchmarked off "reduction of transport losses"

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Reduction of transport losses (transport, storage, market)	Prevent post-harvest crop losses during storage and transportation through measures such as building better storage and improving transportation efficiency	CHN IND	▪ Potential loss reduction of 20% in IND ▪ Yield improvement of 5% for grains, 10% for cash crops in CHN ▪ Potential assumed to be 5% today, and increases to 65% by 2030 % in CHN	▪ Implementation of low-cost fittings to transportation costs $150 in IND, lasting 2 years ▪ CapEx of 0.07 $/m³ for better storage and transportation facilities in CHN
Soil techniques/ no-till agriculture (irrigated)	Techniques to reduce tillage; laser land leveling to reduce runoff and better drain lands	CHN IND RSA	▪ Applicable to annuals, i.e. no fruits, tree-crops; all crops in CHN ▪ Yield increase 5% in IND and CHN, 15% in RSA (in some cases this relies on disease resistant varieties or IPM) ▪ Gross water savings 12% ▪ Potential on 20% of lands by 2030 in IND, 90% in RSA, 70% for grains and 20% for cash crops in CHN	▪ Reduced cost for fertilizer, labor, fuel; increases for pest control, weed control ▪ Operational savings of 40-60 $/ha ▪ Assumes laser levelers are purchased by a centralized group in IND, and has full utilization over year (45 $/ha) ▪ CapEx 320 $/ha in RSA
Soil techniques/ no-till agriculture (rain-fed)	Techniques to reduce tillage; laser land leveling to reduce runoff, better drain lands and conserve "green water"	CHN RSA	▪ Applicable to annuals, i.e. no fruits, tree-crops in RSA, all crops except rice, vegetables in CHN ▪ Yield increase 15% (in some cases reliant on disease resistant varieties or pest management) ▪ Gross water savings 12% ▪ Potential on 90% of lands by 2030 in RSA, 80% for grains and 25% for cash crops in CHN	▪ Reduced cost for fertilizer, labor, fuel; increases for pest control, weed control ▪ Operational savings of 14 $/ha in RSA

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Sprinkler conversion to micro-sprayer	Use micro-sprayers in areas where drippers are not practical; consume less water than sprinklers	RSA	▪ Applicable crops oil crops, vegetables, roots and tubers, sugarcane, fruits, cotton ▪ Yield improvement and gross water savings 10%	▪ Reduced fertilizer, fuel, electricity and pest control and increased repair—50 $/ha savings ▪ CapEx of 4,900 $/ha
Sprinkler irrigation	Increase yield and irrigation efficiency (e.g., through reduced evaporation)	BRA CHN IND RSA	▪ Applicable to grains (excluding rice) and vegetables ▪ Yield increase 5-10%, up to 20% in BRA and CHN ▪ Gross water savings 12-15%, up to 41% in BRA ▪ Potential 33% of furrow irrigated land in BRA, 50% of crop area in IND (applicable where wheat and maize are irrigated by flood irrigation using groundwater); 40% for grains, 30% for vegetables in CHN	▪ CapEx of ~200 $/ha for a small mobile sprinkler unit in CHN; CapEx in IND 564 $/ha, 1,200 $/ha in BRA, and 2,400 $/ha in RSA ▪ Operational savings of 50-100 $/ha (crop, country dependent) in fertilizer, fuel, electricity and labor
System of rice intensification (SRI)	Improve rice planting, irrigation and production practices	CHN IND	Applicable to rice Yield increase 5% in CHN, 50% in IND Gross water savings 15% in IND Potential 40% of total crop area by 2030 in IND, 95% in CHN	Savings of 11% on overall rice cultivation costs; reduces seed, fertilizer, pesticide costs and in some cases energy cost in IND
Trashing stubble	Trashing stubble instead of burning improves water retention and increases moisture levels	BRA RSA	Applicable to irrigated sugarcane (effect for rain-fed included under no-till) Yield increase 10%, assumes precision farming as enabler Potential area: move from an estimated 90% today to 95% in 2030 (reach 50% of subsistence farmers) in RSA, up to 25% in BRA	Reduced fertilizer, fuel, electricity and pest control and increased repairs, labor with minor net effect in BRA 42 $/ha increased cost of seeds in RSA

Industrial demand measures

Measure	Description	Countries	Key assumptions	Key cost assumptions
Better housekeeping	Measures involving a better water management plan with increased monitoring	BRA	▪ 18% average industrial leakage ▪ 15% reduction in consumption across sectors	▪ CapEx ~$1m per project ▪ Less effluent treatment
Closing circuits (pulp & paper)	After treatment reuse of water evaporated in pulp digester process	BRA	▪ 25% reduction in consumption ▪ 30% adoption	▪ CapEx ~$2m per project ▪ Less effluent treatment and better thermal efficiency
Concealed pulp filtering (pulp & paper)	During the pulp filtering process, use concealed techniques to avoid water loss	CHN	▪ 30 m^3/t reduction in consumption ▪ 70% penetration by 2030 ▪ Savings spread over six main paper producing basins	▪ $0.8m CapEx for 40 kt/year plant, annualized over 15 years ▪ Small incremental OpEx, mainly for electricity
Condensed water cooling (power)	Raise the ion/ contaminates concentration limit in circulated cooling water through various treatment techniques to reduce wastewater discharge and fresh water withdrawal	CHN	▪ Suitable for both new and old closed-loop plants ▪ 33% reduction in consumption ▪ 100% penetration by 2030 (90% increment over 2005)	▪ Relatively small CapEx (assumed 1/4 of OpEx) ▪ Water savings partially offset by higher energy and chemical cost ▪ Unit cost for required treatment to condense 0.2-0.8 $/m^3$
Condensed water cooling (steel)	Raise the ion/ contaminates concentration limit in circulated cooling water through various treatment techniques to reduce wastewater discharge and fresh water withdrawal	CHN	▪ Water consumption 70% of withdrawals ▪ 23% reduction in consumption ▪ 90% penetration by 2030 ▪ Most savings occur at Hai and Yangtze basins due to large steel productions	▪ Relatively small CapEx ▪ Higher energy and chemical cost ▪ Extrapolated from power cost

Measure	Description	Countries	Key assumptions	Key cost assumptions
Dry coke quenching (steel)	New technique for quenching which saves water and generates steams for electricity generation	CHN	▪ 70% penetration by 2030, from 10% in 2005 ▪ reduction in consumption 1.1 m^3/t of steel	▪ $66m CapEx for facility of 3m tons per year, annualized over 15 years ▪ Savings mostly energy ▪ Slightly higher maintenance cost
Dry cooling (power)	Replace traditional water-cooling system with air cooling	CHN	▪ Limited to new plants ▪ 21% penetration by 2030, from 3% in 2005 ▪ 82% reduction in water consumption	▪ Incremental CapEx of $118m compared to wet-cooling ▪ Annualized over 30 years ▪ Higher energy cost due to low efficiency
Dry debarking (pulp & paper)	Process of removing bark from logs without use of water	RSA	▪ Dry debarking effluent volume: 0.1 - 0.5 m^3/ m^3 wood ▪ Wet debarking effluent volume: 0.6-2.0 m^3/ m^3 wood ▪ 75 % reduction in water consumption	▪ Higher CapEx ($5m for 1,500 Adt/d plant[39]) same OpEx as wet debarking, except for water savings
Dry de-dusting (steel)	Use air to de-dust instead of water	CHN	▪ Limited to new plants ▪ 80% penetration by 2030, from 30% in 2005 ▪ 25% reduction in water consumption	▪ $18m CapEx for facility of 1.5 m tons per year, annualized over 15 years ▪ ~60% savings from water, ~40% from energy ▪ Additional maintenance cost offset total savings

39 Adt/d = air-dried tons per day

Measure	Description	Countries	Key assumptions	Key cost assumptions
Dry lubrication (food & beverages)	Technology replacing wet lubrication with Teflon/silicon-based product thereby eliminating need for water	RSA	▪ 2.5% of water used for conveyor lubrication ▪ 100% reduction for this use	▪ Savings from water and wet lube ($6 per gallon) ▪ Additional CapEx of $60,000 for ~8 million barrels/year plant ▪ Incremental servicing cost for dry lube system
Dust suppression on haul roads (mining)	Water use to suppress dust on haul roads can be reduced significantly by adding a chemical additive that aids in dust suppression	RSA	▪ 1.38 million m^3 currently used for dust suppression in 55Mt ore production plant ▪ 80% reduction assumed	▪ Increased cost for chemical Dustbloc (~$1.1/l) ▪ Mixing ratio 20:1
Fluidized bed combustion (power)	Switch from pulverized coal (PC) technology to fluidized-bed technology (FBC) for new build	RSA	▪ Reduction in water requirement 0.1 m^3/MWh ▪ Application of lever to new capacity from 2015 onwards	▪ CapEx Ultra-supercritical PC $1360/kWe vs subcritical CFB $1330/kWe ▪ OpEx PC $4.69/kWe vs CFB $4.68/kWe
Industrial leakage reduction	Reduction of leaks in water pipes in industrial facilities	RSA	▪ 18% leakage as percentage of total withdrawals ▪ Assumed 30% reduction	▪ Annual leak fixing cost of $98,000/ million m^3
Industrial water efficiency	Aggregated potential of industrial measures	IND	▪ Weighted average of 14 industrial measures focusing on power, textile, pulp & paper, steel, and manufacturing	▪ Weighted average of 0.00 $/$m^3$ water released across all 14 measures
Intermediate water reuse (pulp & paper)	Treat and reuse the wastewater generated in the intermediate steps of the manufacturing process	CHN	▪ 60% penetration by 2030, from 15% in 2005 ▪ 50 m^3/t reduction in water consumption ▪ Savings spread over six main paper production basins	▪ CapEx of ~$2,500 for pumps and pipes ▪ Annualized over 15 years ▪ Small incremental OpEx, mainly for electricity

Measure	Description	Countries	Key assumptions	Key cost assumptions
Mine water treatment (mining)	Opportunity to pump out water sitting in unused underground mines, treat it to a suitable level and reuse in operation or sell to other users	RSA	▪ 0.2 million m³/day available to pump	▪ Case study $37m for 25,000 m³/ day capacity ▪ Also requires pipeline to plant for treatment and use of water
More efficient washing equipment	Reduce water consumption in washing of industrial facilities and equipment, e.g., through the installation of spring valves on water hoses	RSA	▪ Limited to pulp & paper in RSA with 15% evaporation ▪ 10% reduction in water consumption	▪ Higher CapEx ($ 1,620 for water savings of 0.077 million m³ p.a.), same OpEx as reference case, except for water savings
Paste tailings (mining)	In conventional mines, waste (30-50% solids) is pumped to tailings dam and lost through evaporation; paste tailings uses one or two-step process to thicken and filter tailings to higher solids concentration and recycle water	RSA	▪ Mining evaporation 84% ▪ Reduction in water loss from 40 to 26% ▪ 44 equivalent RSA projects	▪ ~$2m incremental CapEx ▪ Savings from water and recovered reagents, but higher energy cost
Radical water (food & beverages)	Electrically charged water acts as a detergent and antimicrobial agent, used as a substitute for chemical cleaning agents	RSA	▪ 20% of water used for cleaning ▪ 70% reduction in water requirements for cleaning	▪ CapEx of ~$100,000 -200,000, increased cost for salt of ~$100/t
Recycling/ reuse of treated water (petro-chemical, pulp & paper, steel)	Optimization of in-plant wastewater reuse for low quality demand uses	BRA	▪ 20% reduction in consumption	▪ Additional cost with chemicals for treating effluent, higher treatment costs of water treatment
Recycling of treated service water (mining)	Optimization of in-plant wastewater reuse for low quality demand uses	RSA	▪ Mining evaporation 84% ▪ 8% reduction in potable water spend	▪ Increased treatment cost of $0.3m-$0.82m for an additional 1.8 million m³ p.a.

Measure	Description	Countries	Key assumptions	Key cost assumptions
Reusing condensates	Increasing effectiveness of steam circuit in the petrochemical, pulp & paper, ethanol and steel industries	BRA RSA	▪ Pulp & paper 15% evaporation; other manufacturing 65% in RSA, 30-80% in BRA ▪ 5% reduction in water consumption ▪ 20% adoption in BRA in steel, 15% in petrochemicals, 100% in pulp & paper	▪ ~$183,000 CapEx for water savings of 0.27 million m^3 p.a.
Sensitivity sensors	Automation of water usage in industrial processes to an optimal threshold through monitoring of specific characteristics (e.g., ph level)	BRA	▪ 25% reduction in consumption	▪ $7.5m for ~600 small-scale projects ▪ Savings on effluent treatment
Spring valves	Installation of efficient valves for industrial cleaning applications	BRA	▪ 60-80% process water in BRA (depending on industry) ▪ 10% reduction in process water consumption	▪ CapEx $1,620 for savings of 77,266 m^3 ▪ Less effluent treatment
USC technology (power)	Ultra-super critical technology, improving fuel efficiency by 10% over super critical technology.	CHN	▪ 9% reduction in water consumption ▪ 35% penetration by 2030, from 2% in 2005 ▪ High potential uptake driven by ▪ Energy savings ▪ CO2 reduction ▪ Improving technology maturity ▪ Increasing manufacturing capacity	▪ USC CaPex is 10% higher than SC ▪ OpEx savings in energy and water cost

Measure	Description	Countries	Key assumptions	Key cost assumptions
Wastewater reuse (power)	Install wastewater treatment system and recycle wastewater	CHN	▪ Suitable for both new/old plants ▪ Agnostic to cooling system types ▪ 40% penetration by 2030 ▪ Savings limited to ~900 m^3/GWh as wastewater accounts for <1/3 of water consumed	▪ CapEx ~$17m annualized over 30 years ▪ Higher energy cost ▪ Reduced cooling water and other water consumption
Wastewater reuse (steel)	Install wastewater treatment system and recycle wastewater	CHN	▪ ~24% water demand reduction if fully implemented ▪ 50% penetration by 2030, from 18% in 2005	▪ $1.7m CapEx for facility of 1.5 m tons per year, annualized over 15 years ▪ Water savings partially offset by higher energy cost
Wastewater reuse (textile)	Treat and reuse the discharged wastewater in textile factory internally	CHN	▪ 70% penetration by 2030 ▪ Average savings of 33% to 50% ▪ Major impacts in Yangtze, Southeast (~37% and ~33% of textile production respectively)	▪ ~$160,000 CapEx for 120 million m p.a. plant, simplicity in treatment ▪ Annualized over 15 years ▪ Savings from water, but higher energy cost
Wastewater reuse (other)	Install wastewater treatment system and recycle wastewater	CHN	▪ Assumes similar wastewater reuse measures can be applied to other industries ▪ Assumes wastewater reuse will achieve zero-discharge (33% of savings) ▪ 50% penetration by 2030	▪ Cost based on average of other wastewater reuse examples ▪ Water savings partially offset by higher energy cost
Water pressure reduction	Reduce pressure in system	BRA RSA	▪ 18% leakage as percentage of total withdrawals, 65% evaporation (mining 84%) ▪ 5% reduction in water consumption	▪ Case study $12,000 outlay to save 1.7 million m^3 in RSA; savings on electricity and water treatment cost

Measure	Description	Countries	Key assumptions	Key cost assumptions
White water reuse (pulp & paper)	Reuse white water generated by paper machine as new water	CHN	▪ 70% penetration by 2030 ▪ Average savings of 10 m^3/t	▪ CapEx $1.3m for 150-kt/year plant, annualized over 15 years ▪ Saves water and energy ▪ Slightly higher maintenance cost

Municipal and domestic demand measures

Measure	Description	Countries	Key assumptions	Key cost assumptions
Bulk leakage	Reduction of leaks in bulk water transport	RSA	▪ Bulk leakage 2% ▪ 0.3% reduction assumed	▪ Case study shows cost of $3.95 million vs. savings of $3.56 million for 5.5 million m^3 saved
Commercial & public leakage	Reduction of leaks on commercial and public premises	BRA CHN	▪ Commercial leakage 4% in BRA ▪ Water wasted 0.017 million m^3/leak/year in BRA ▪ Reduction potential of 5-10% in CHN	▪ Avg. of $2.40 per leak in BRA ▪ ~0.1$/$m^3$ for water balance test in CHN
Dishwashers	Use of water-efficient dishwashers for doing dishes	BRA	▪ 5% dishwasher penetration in 2005 growing to 50% by 2030 in BRA ▪ 90% penetration of efficient dishwashers for new machines, 50% for retrofits in Dubai ▪ Saves 25,400 m^3/appliance/year in BRA ▪ Saves 3,500 l/hh/year for replacements of dishwashers in Dubai, 19,000 l/hh/year compared to washing by hand	▪ $980 for efficient dish washer in BRA, ▪ 1 machine per 3.2 people with dishwasher in BRA, 4.5 in Dubai

Measure	Description	Countries	Key assumptions	Key cost assumptions
Dual-flush toilets (new and retrofits)	Installation of water-saving dual-flush toilets	BRA CHN RSA	▪ 49% households with toilets in 2005, increasing 1% p.a. in RSA ▪ 5% of toilets replaced each year; 1% p.a. of dual-flush vs. standard toilet purchases until 2010, then increase by 2% each year in RSA ▪ 40% households' replacement for dual-flush toilets in 2030, 50% of new toilets in BRA ▪ Dual-flush toilets use 18 l/c/d vs. 75 l/c/d in RSA, savings of 4,400 m^3 per capita and per year in BRA	▪ $38 for standard vs. $81 for dual-flush toilet in BRA, plus $24 installation ▪ $116 per dual-flush toilet in RSA ▪ Incremental cost of ~$160-250 in CHN
Faucets (new and retrofit)	Installation of water-efficient faucets with aerators and pressure controllers to keep the water flow at desired levels	BRA CHN RSA	▪ 54% households (hh) with faucets in 2005, 2% increase p.a. until 2030 (90% max.) in RSA ▪ 1% p.a. of efficient vs. standard faucet purchases until 2010, then increase by 2% p.a. in RSA ▪ 55% hh' replacement with water-efficient faucets by 2030, 70% of new hh in BRA ▪ 90% penetration of new faucets in Dubai in 2030, 50% for retrofits ▪ Efficient faucets use 20 l/c/d vs. 40 l/c/d in RSA, saving 7,300 m^3/ person/ year in BRA; 70% savings in Dubai	▪ $4 incremental cost for water-efficient faucet, $10 installation in BRA ▪ $22 per faucet in RSA ▪ Incremental cost of $30 in CHN

Measure	Description	Countries	Key assumptions	Key cost assumptions
Household landscaping	Introduction of water-efficient techniques (mulching) in private gardens	RSA	▪ 50% of middle income and 100% of high income households with gardens ▪ 30% of household water demand for gardens ▪ 30% of households using mulching in 2030 ▪ Savings potential 30%	▪ Incremental cost of $150 per garden
Household leakage	Reduction of leaks in household connections and pipes	BRA RSA	▪ Household leakage 30% in RSA, 4% in BRA ▪ 5% reduction assumed in RSA ▪ Water wasted 0.017 million m^3/leak/year in BRA	▪ Avg. of $2.40 per leak in BRA, $45.37 per household in RSA
Laundry machines	Use of water-efficient laundry machines	BRA CHN	▪ 56% laundry machines penetration in 2005 in BRA growing to 65% by 2030 ▪ 50% share of efficient laundry machines in 2030 in BRA ▪ 70% penetration for new machines in 2030 in Dubai, 50% for retrofits ▪ Saves 23,800 m^3/ appliance/year in BRA	▪ $197 incremental cost for efficient laundry machine in BRA ▪ 1 machine per 3.2 people with laundry machine in BRA ▪ Incremental cost of $300 in CHN
Municipal leakage	Reduction of water lost through leak detection and repair in water distribution networks	BRA CHN IND RSA	▪ Municipal leakage 30% in RSA, 24% in BRA, 40% in IND ▪ 5% reduction in RSA, 16% in BRA, 5-8% in CHN; in IND, 60% of total leakage by 2030;	▪ Avg. of $38 per leak in BRA ▪ CHN ~ 0.2 $/$m^3$ ▪ RSA case study: cost of $3.95 million vs. savings of $3.56 million for 5.5 million m^3 saved ▪ In IND, between 0.04 -0.38 $/$m^3$

Measure	Description	Countries	Key assumptions	Key cost assumptions
Pressure management (municipal)	Improved pressure management in water distribution system	RSA	▪ 3% water demand savings via pressure reduction ▪ Based on Cape Town and Johannesburg examples (3.34% and 20% respectively)	▪ CapEx of ~$0.6 million, compared to $5-6 million in savings for ~10 million m³ saved
Showerheads (new and retrofit)	Installation of water-efficient showerheads with aerators and pressure controllers to keep the water flow at desired levels	BRA CHN RSA	▪ 54% households (hh) with showers in 2005, 2% increase p.a. until 2030 (90% max.) in RSA ▪ 1% p.a. of efficient vs. standard shower purchases until 2010, then increase by 2% p.a. in RSA ▪ 55% hh replacement with water-efficient showerheads by 2030, 70% of new hh in BRA ▪ Efficient showerheads use 70 l/c/d vs. 105 l/c/d in RSA, saving 18,300 m³/ person/ year in BRA; 36% reduction in consumption in CHN; 90% in Dubai	▪ $6 incremental cost for water efficient shower head, $10 installation in BRA ▪ $13 per showerhead in RSA ▪ ~$50 incremental cost for fixtures in CHN
Wastewater reuse (in commercial buildings)	Use of bio-treatment to recycle wastewater for use in toilets in commercial buildings	CHN	▪ Wastewater treatment system reduces water usage by 30%	▪ Price of equipment processing 10 ton/hr: $40-50k ▪ Increased cost for bio-chemicals and energy
Wastewater reuse (municipal)	Reuse of treated municipal and industrial wastewater as municipal public, industrial cooling water, etc.	BRA CHN	▪ 31% of projected domestic demand becomes sewage treated in 2030 in BRA ▪ 3.5% of sewage treated good for reuse under BAU in BRA ▪ 10% of sewage treated good for reuse under optimum scenario in 2030 in BR ▪ Important water supply in CHN in basins with limited incremental surface and ground water, e.g., Hai, Huang ▪ Underdeveloped piping networks for collection and reuse major barrier in CHN	▪ Incremental treatment cost of 0.4 $/m³ in BRA ▪ Energy cost ~60% of OpEx

Supply

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Aquifer recharge	Collection of rainwater and artificial recharge of aquifer with collected water	BRA IND RSA	▪ Aquifer recharge depends on rainfall and the creation of the requisite infrastructure ▪ Assumes 5% of the total potential of can be developed in RSA, 10% in BRA ▪ In IND 75% avg. recharge efficiency (% of water that reaches the aquifer form the recharge structure); 90% extraction efficiency (% of recharged water that can be extracted)	▪ Costs about 20% more than groundwater abstraction in RSA, 50% in BRA; due to infrastructure construction and maintenance for recharge ▪ In IND, structures >0.2 million m³ with percolation tanks, sub-surface dyke, revival of ponds; <0.2 million m³ check dams, contour bunds, gabion structures
Dams & reservoirs – large	Surface water storage through dams & reservoirs with a total capacity greater than 100 million m³	CHN RSA	▪ Dams & reservoirs are restricted by surface runoffs, most of the incremental supply in CHN in southern basins, Yangtze and Pearl ▪ Based on Department of Water Affairs and Forestry (DWAF) data in RSA	▪ Very large upfront CapEx ▪ OpEx ~10% of CapEx ▪ Benchmarked off avg. of all dam costs per m³ at actual existing costs in RSA
Dams & reservoirs – small	Surface water storage through dams & reservoirs with a total capacity less than 100 million m³	BRA CHN	▪ Based on DAEE data in BRA ▪ Dam & reservoir are restricted by surface runoffs, most of the incremental supply in CHN in southern basins, Yangtze and Pearl	▪ Average of global dams costs taken per m³ at actual and reduced by 20% for Brazil ▪ Upfront CapEx 2-5 $/m³ in CHN, the smaller the more expensive
Dams & reservoirs – raisings	Raising of dams to increase storage capacity	RSA	▪ Based on DWAF data ▪ Total surface water potential may not be totally achieved due to technical and environmental constraints	▪ Average of all dams costs taken per m³

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Desalination SWRO	Sea Water Reverse Osmosis (SWRO) is a reverse osmosis desalination membrane process	BRA CHN RSA	▪ Calculated at 100 million m³ for São Paulo, principally in the UGRHI of Baixada Santista ▪ In CHN, mainly in Huang, Huai and Hai basins; Tianjin, Qingdao, Dalian and Xiamen are the pioneer desalination applications in CHN ▪ Principally in 6 WMAs in RSA: Berg, Breede, Olifants- Doering, Gouritz, KZN and Fish	▪ Energy intensive (3-4.5 kWh/m³), >75% of OpEx is energy, ▪ National average in BRA 0.71 $/ m³, in RSA 0.79 $/m³; may increase to 0.91 $/m³
Desalination (thermal)	Desalination of water through thermal technologies facilities	CHN	▪ Usually co-located with power plants with limited production capacity ▪ Thermal desalination will gradually be replaced by SWRo technologies due to lower energy cost	▪ Energy intensive (7-10kWh/m³), ~2x of SWRO ▪ 1t of steam per 10 m³ water production
Gravity transfers	Interlinking of water management areas to transfer water resources from surplus basins to other basins by gravity	RSA	▪ Based on DWAF data	▪ Based on DWAF data on projected OpEx ▪ No energy is used ▪ Avg. capital costs of dam construction also incorporated, because majority of transfers are sourced from dams

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Groundwater pumping	Extract water resources beneath the ground through well and pumps	BRA IND RSA	▪ Based on DWAF data in RSA ▪ The total estimated potential in RSA is 6,000 million m^3, thereof 934 million m^3 potential in addition to existing supplies; in BRA 3,910 million m^3 out of 11,479 million m^3 ▪ In IND, max. avg. ground-water abstraction ratio by 2020 80%; max. increase from current abstraction ratio 35% ▪ Deep tube wells for abstraction ratio between 70% and 80% in IND 20%, below 10%	▪ Total cost ~0.09 $/$m^3$, thereof ~25% for energy in RSA; based on exemplary data from DWAF ▪ In BRA, CapEx of $ 40,000 per well for ~45,000 wells; maintenance $900 p.a. ▪ Calculated for avg. depth of 120m, with 315 million m^3/year flow rate ▪ In IND 0.9 $/ft drilling, 2.2 $/ft casing, pump $900-2,200; depth 150 ft for shallow, 400 ft for deep tube wells
Groundwater pumping – deep	Extract water resources 120-150 meters beneath the ground to surface through well and pumps	CHN	▪ 120 meter depth ▪ Each pump supplies 50 Mu[40] farm lands in CHN ▪ ~250 m^3 water need each Mu per season , avg. 1.2 seasons in CHN	▪ Drilling cost 130 $/m in CHN , pump $2,500 ▪ Lifetime of 20 years ▪ Energy cost account for >70% of the OpEx
Groundwater pumping – shallow	Extract water resources 40-60 meters beneath the ground to surface through well and pumps	CHN	▪ 40 meter depth ▪ Each pump supplies 50 Mu farm lands in CHN ▪ ~250 m^3 water need each Mu per season , avg. 1.2 seasons in CHN	▪ Drilling cost 130 $/m in CHN , pump $1,300 ▪ Lifetime of 20 years ▪ Energy cost account for >70% of the OpEx
Inter-basin water transfer	Interlinking of river basins to transfer river water resources from surplus basins to other basins	CHN	▪ South to North water transfer project (east, central and west line) will provide >10 billion m^3 by 2015 ▪ Incremental water supply in Huang, Huai, Hai basins where local water supply is limited	▪ High CapEx ▪ Estimated using south to north water transfer phase 1

[40] 1 Hectare = 15 Mu

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Intra-basin water transfer	Interlinking of rivers within a basin to transfer river water resources from surplus river to others	CHN	▪ Particularly in Hai, Huai, Northwest ▪ Scale projects remains <1 billion m^3 each	▪ High CapEx ▪ Benchmark with south-to-north water transfer intra-basin part ▪ Energy cost ~25% of OpEx
Large-scale irrigation infrastructure	Major irrigation infrastructure projects such as large stream dams and reservoirs	IND	▪ Completion year of projects under completion - 2010 ▪ Potential—15 million ha, completion by 2020-12 million ha, completion by 2030	▪ CapEx $3800/ha ▪ OpEx $7/ha p.a.
Large-scale irrigation systems – rehabilitation	Rehabilitation of existing infrastructure includes renovation, de-silting, maintenance and set-up of management infrastructure	IND	▪ Total potential 5 million ha, 100% penetration by 2020 ▪ Water requirement 10,000 m^3/ha	▪ Rehabilitation cost $1,000/ha ▪ OpEx 10$/ha p.a.
Last-mile irrigation	Bridging the gap between irrigation potential created and utilized. Involves creation of command area, set-up of management systems and completion of the last-mile of delivery infrastructure	IND	▪ Gap between total created capacity for irrigation and utilized potential that can be rehabilitated to utilized, 2020 (2030)—70% (additional 20%); 9 million ha in total ▪ Water requirement 10,000 m^3/ha	▪ Rehabilitation cost $1,200/ha ▪ OpEx 10$/ha p.a.
Local water conveyance	Conveyance of local surface water through channels or pipes covering short distances (10 - 30km) mainly using gravity	CHN	▪ Average conveyance distance ~50km ▪ Average annual water supply ~100 million m^3	▪ CapEx ~40-50$/m ▪ OpEx ~10% of CapEx, mainly labor, materials, assumes no electricity cost

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Local water pumping	Lifting of local surface water through short lift (avg. 10-20m) pumps	CHN	▪ Each pump supplies 50 Mu[41] farm lands ▪ ~250 m^3 water need each Mu per season , avg. 1.2 seasons ▪ Account for 25% of total surface water usage	▪ Pump cost ~$1,500, useful life 10 years ▪ Pump capacity 15 m^3/h, ▪ Avg. lift 15m
National River Linking Project (NRLP)	Interlinking of river basins to transfer river water resources from surplus basins to other basins	IND	▪ Only 15% of the total capacity considered ▪ Total water availability (50% reliability) 178,000 million m^3 ▪ 40% availability by 2030	▪ Total cost of the project $120 billion ▪ OpEx $7/ha/ p.a.
Pumped transfers	Interlinking of water management areas to pump water resources from surplus basins to other basins	BRA RSA	▪ Based on DAEE data in BRA ▪ Based on DWAF data in RSA	▪ Based on DAEE/ DWAF data on projected OpEx ▪ Avg. capital costs of dam construction also incorporated, because majority of transfers are sourced from dams
Rainwater harvesting	Collection of rainwater on rooftops for domestic use (in IND for groundwater recharge)	BRA IND RSA	▪ Avg. roof top area of houses in BRA is 70 m^2, 400 m^2 for apartment buildings; in RSA 50 m2 (government housing) ▪ Avg. rainfall of 1,200 mm in BRA, 450 mm in RSA ▪ Potential 4.6 million houses in 2030 in RSA; in IND 16 million	▪ Construction of tank ~$600-900; ~900,000 tanks will need to be installed in BRA ▪ No or minimal energy use required ▪ Maintenance in IND 10% of CapEx

41 1 Hectare = 15 Mu

Measure	Description	Countries	Key volume assumptions	Key cost assumptions
Removal of invasive alien plants (IAP)	Removal of IAPs that waste 7% of water resources; reduce the ability to farm; intensify flooding and fires; cause erosion, destruction of rivers, siltation of dams and estuaries, and poor water quality	RSA	▪ DWAF figures show that IAPs use 7% of surface water supply, doubling by 2030; therefore total lever size 14% of 2030 water supply divided among each of the 20 years ▪ Principally in Western Cape and KZN areas	▪ Actual costs as per DWAF figures of WfW program divided by the total size of the water saving in 2030 ▪ Total cost estimated at $75m p.a.
Sea water direct use	Direct use of seawater, mostly for industrial cooling and municipal water use	CHN	▪ >80% to be used for industrial cooling in costal areas ▪ Limited adoption in municipal usage, e.g.: toilet flushing, fire-fighting, street cleaning, etc	▪ Benchmarked with local water pumping
Small-scale irrigation infrastructure projects	Minor irrigation infrastructure projects such as small dams built closer to communities, water used during in-season dry spells or to augment rainfall	IND	▪ Potential 1.5 million ha ▪ Water requirement 10,000 m^3/ha	▪ CapEx 2,022 $/ha ▪ OpEx $7/ha/ p.a.

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