Peak Water: The Preeminent 21st Century Commodity Story

SUMMARY

New developments in water treatment, desalination and agriculture offer opportunities.

Over the past half century, there has been much discussion of "peak oil." This term, coined by geoscientist M. King Hubbert in 1956, was based on the premise that US oil production would peak by 1970. Then, in 2007, author Richard Heinberg extended that concept to "peak everything"—peaks in population, food production, climate stability and freshwater availability. Indeed, as we've noted before (see *Water: The Perfect Storm,* June 2010), water may turn out to be the biggest commodity story of the 21st century, as declining supply and rising demand combine to create the proverbial "perfect storm." Freshwater stress, already at challenging levels, is likely to deteriorate, as water withdrawals keep rising, supply decreases due to increasing drought, snow cover melts and groundwater abstraction grows (see Figure 1, page 2). ▸

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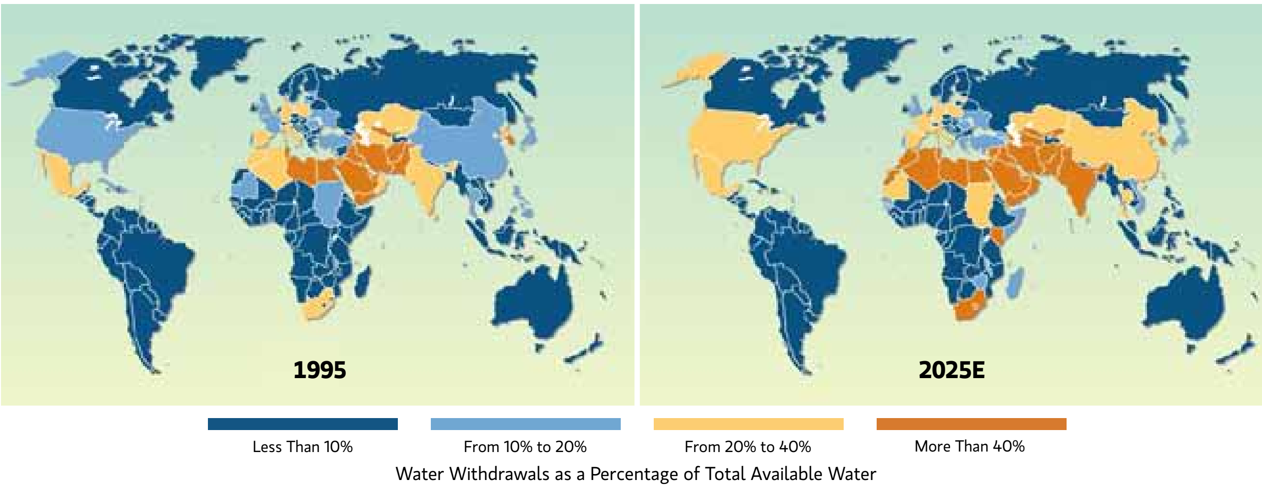
Figure 1: Forecasting an Increase in Water Withdrawals

Declining supply and rising demand for freshwater is leading to a sharp increase in water withdrawals. For example, the US withdrawal rate is forecast to be between 20% and 40% by 2025, up from between 10% and 20% in 1995.

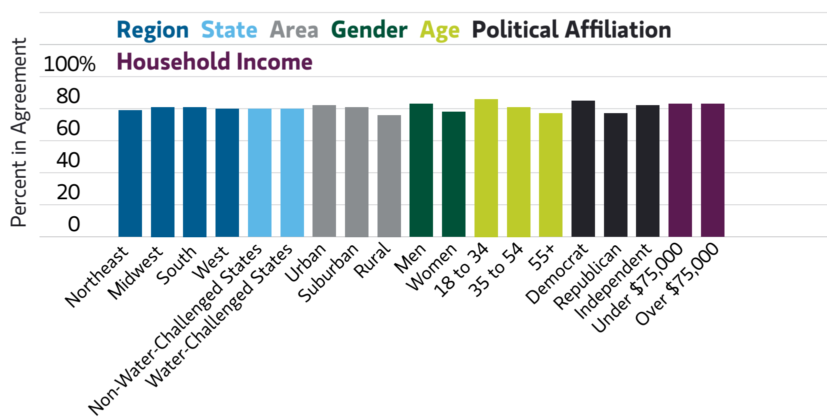


Source: United Nations Environment Programme as of February 2002

▶ According to ITT's *Value of Water Survey,* 95% of Americans rate water as "extremely important," which is more than give that priority to any other service they receive, including heat and electricity; nearly two-thirds say they're willing to pay more now to ensure long-term access to clean water. A substantial majority of Americans believe significant reform is needed, regardless of region, residence, age, political affiliation or household income (see Figure 2).

Figure 2: Reform of the Nation's Water Supply Is Needed

According to ITT's Value of Water Survey, *a substantial majority of Americans believe significant water-industry reform is needed, regardless of region, residence, age, political affiliation or household income.*



Source: ITT as of September 2010

Solving the Challenge

Given the challenging supply/demand situation, the global water industry is expected to undergo a substantial transformation in the near future. Businesses will need to make further investments in water technology, and utilities will need to devote more money to water infrastructure. Capital expenditures on water infrastructure are expected to grow to $131 billion in 2016 from $90 billion in 2010, according to Global Water Intelligence (GWI). Sales of water- and wastewater-treatment equipment to industrial users are expected to rise to $22 billion by 2016, up from $14 billion in 2010, a 7.8% compound annual growth rate (see Figure 3, page 3). Much of this investment growth will be driven by changing financial models in the municipal water sector. Traditionally, less than half of the money invested by utilities is derived from their own operations, with the rest of the costs being paid by local governments. Given the increasing financial pressure on the public sector, this model is no longer sustainable. Governments will expect utilities to finance themselves to a greater degree in the future, and the proportion of capital expenditure from operating cash flow is expected to rise to 62% in 2016 from 44% in 2010.[1]

Despite challenges in transforming to a new financial model, greater financial independence for water utilities may be liberating for the water sector, as

Figure 3: Spending Growth in the Global Water Industry

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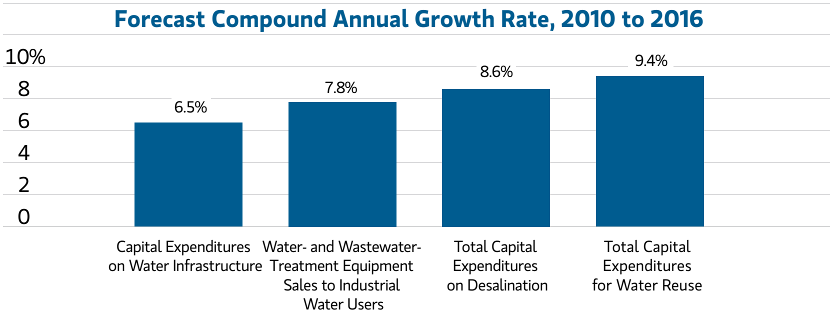
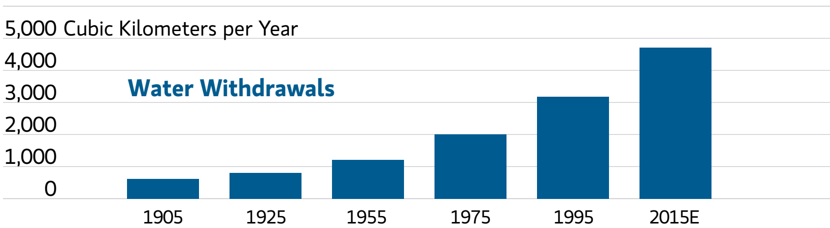


Source: Global Water Intelligence as of March 2010

Figure 4: Long-Term Growth in Water Withdrawals

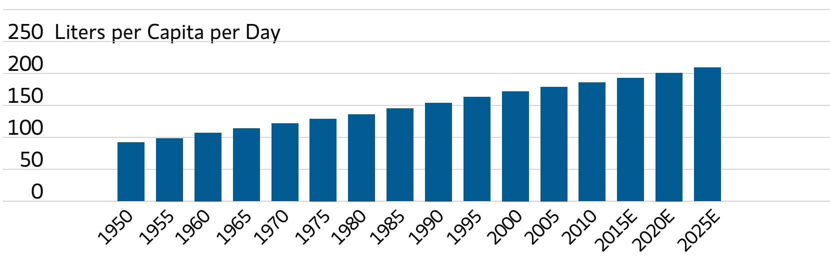
During the past century, global water withdrawals have increased six-fold. In the 20 years between 1995 and 2015, withdrawals are expected to grow nearly 50%.



Source: Global Water Intelligence as of March 2010

Figure 5: Growth in per Capita Domestic Water Demand

Population growth is the major contributor to elevated global water-withdrawal levels. Even so, the rise in demand for water has outpaced population growth by a factor of two.



Source: Global Water Intelligence as of March 2010

evidenced by an emerging group of high-performance, self-financing utilities.

Private water financing was less popular in the 2000s, but this trend is expected to be reversed as municipalities attempt to rein in spending and balance their budgets. Private-sector participation in the water industry should benefit from increased demand for advanced water and wastewater technologies, particularly those involving desalination and water reuse. While more than a decade ago fewer than 10% of large-scale desalination plants were privately financed, 57% of currently proposed large-scale desalination plants are expected to be financed through private investors.[2]

Total capital expenditure on desalination is projected to increase to $18 billion in 2016 from $11 billion in 2010. Capital expenditures for water reuse are also expected to reach $8.4 billion in 2016, up from $4.9 billion in 2010—a 9.4% compound annual growth rate (see Figure 3). China is projected to surpass the US as the largest market in the world in terms of capital expenditures in the water sector, and technology and finance should continue to be the primary drivers of change in the global water industry.[3]

The Problem

WATER WITHDRAWAL

The amount of water withdrawal as a percentage of the total water available is forecast to rise substantially by 2025. As population growth continues, the number of people affected by water stress and scarcity will increase significantly. During the past century, global water withdrawals have increased six-fold (see Figure 4).

Even with population growth being the major contributor to elevated global water-withdrawal levels, the rise in demand for water has outpaced population growth by a factor of two (see Figure 5).

DROUGHT

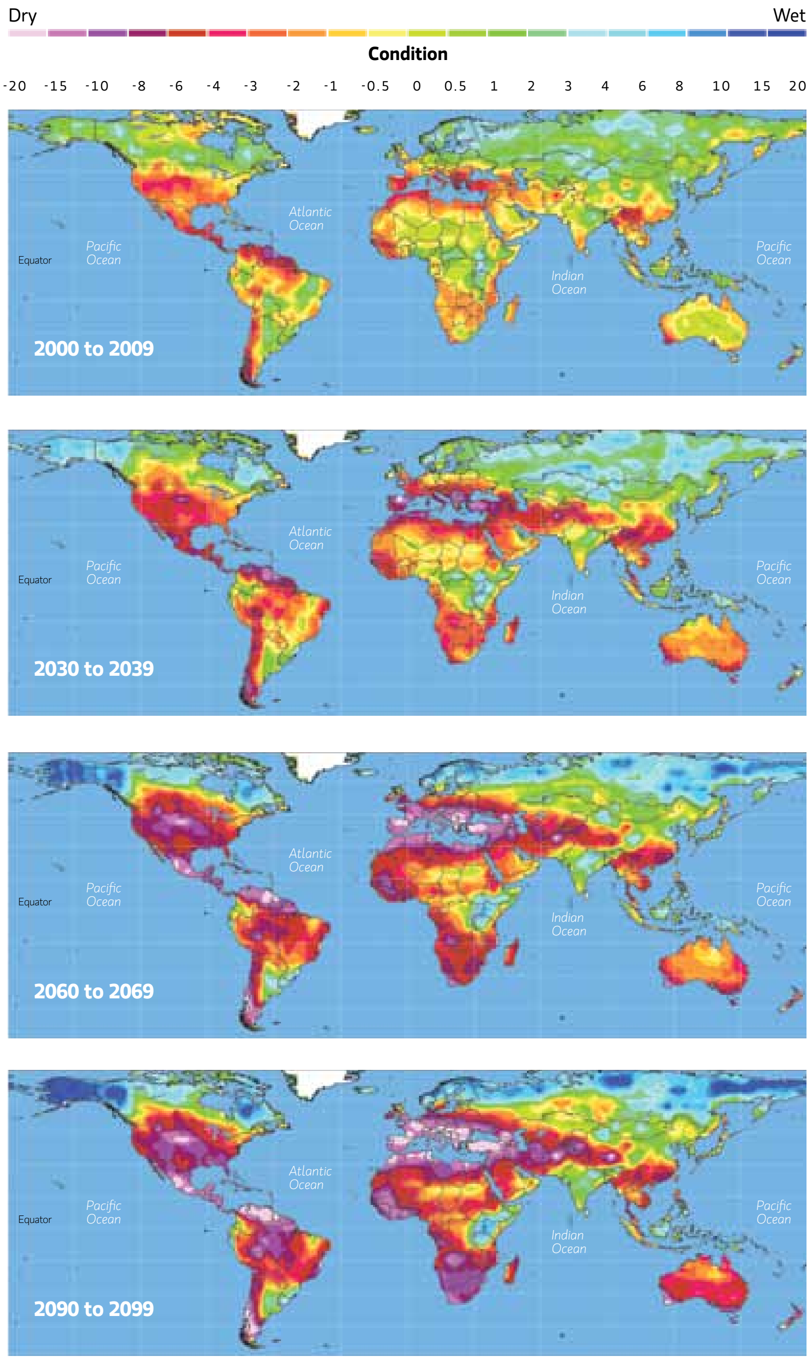
Steadily increasing temperatures associated with climate change and widespread exploitation of water resources across the globe have made droughts a recurring and growing threat. A National Center for Atmospheric Research (NCAR) study concluded that the US and many other populous countries face an increased threat of severe drought in the coming decades.[4] The majority of the western two-thirds of the US is expected to be significantly drier by the 2030s, putting large parts of the nation at risk for extreme drought. Other regions that could encounter considerable drought include most of Latin America, the Mediterranean border regions, Southeast Asia, Southwest Asia, Africa and Australia (see Figure 6). The NCAR study also suggests that drought risk should decline in this century in the majority of Northern Europe, Russia, Canada, Alaska and parts of the Southern Hemisphere. The globe's total land areas, however, should be drier overall.

Even recent heavy rains and flooding may not mitigate drought-induced water shortages. According to Brian Fuchs, a leading climatologist at the National Drought Mitigation Center, temporary spikes in rainfall and flash floods do not sufficiently abate the issue of long-term drought. "Whenever there is a lot of moisture in a short period of time, the potential exists for rapid improvement," says Fuchs. "While that possibility exists, it won't necessarily mean the end of drought in those areas." According to Fuchs, it is very difficult for water to effectively infiltrate the surface of drought-stricken regions because of the subsequent hardening and compacting that occurs in the top layers of soil.

Figure 6: Forecasting a Hotter, Drier Future

The Palmer Drought Severity Index indicates that there is considerable drought risk for the western US, most of Latin America, the Mediterranean border regions, Southeast Asia, Southwest Asia, Africa and Australia.

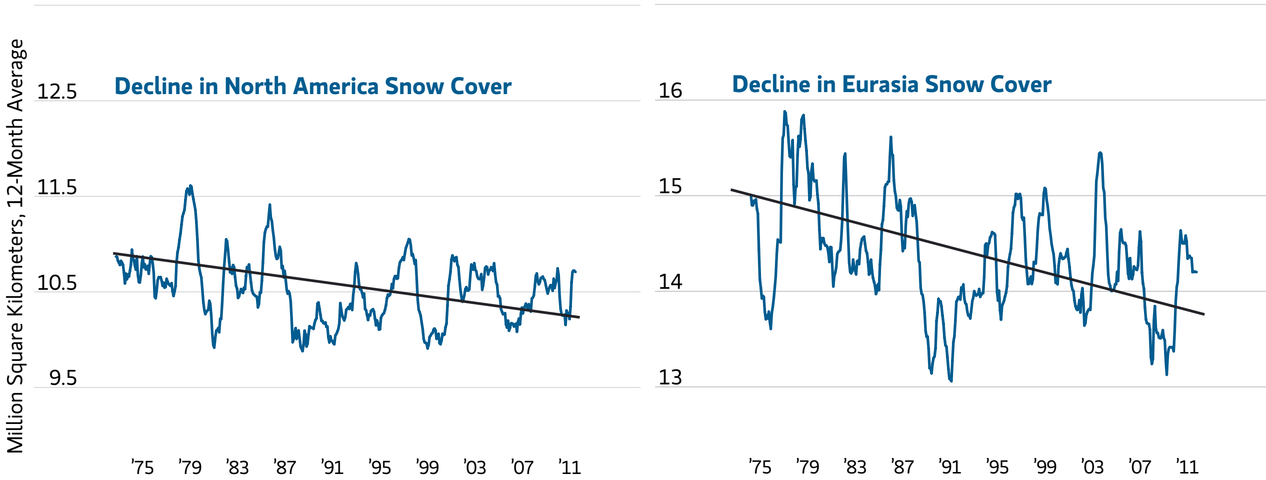
The Palmer Drought Severity Index



Source: University Corporation for Atmospheric Research as of October 2010

Figure 7: Decline in the Northern Hemisphere's Snow Cover

During the last several decades, the amount of ice and snow, especially in the Northern Hemisphere, has declined dramatically as a result of global warming and shifting precipitation patterns.



Source: National Oceanic and Atmospheric Administration as of August 2011

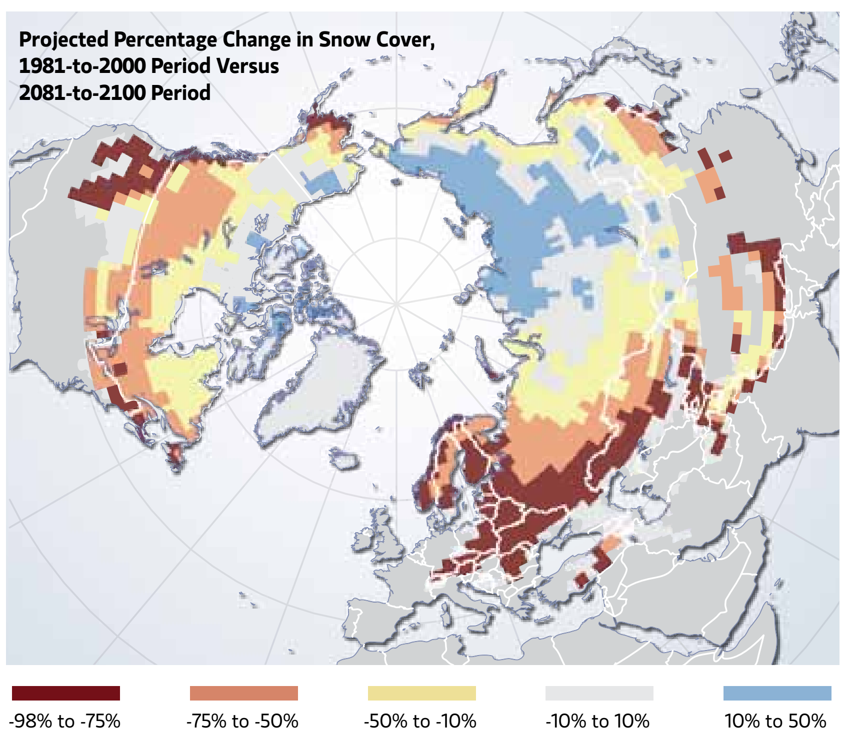
SNOW COVER

The increased climate variability throughout the world has severely affected the earth's snow cover and glaciers (see Figure 7). During the last several decades, the amount of ice and snow, particularly in the Northern Hemisphere, has declined drastically as a result of global warming and shifting precipitation patterns. The reduction in ice and snow volumes has both global and local implications on climate, ecosystems and world water availability. The average monthly snow-cover extent in the Northern Hemisphere has declined 1.3% per decade in the last 40 years, with the largest decreases in the spring and summer months.[5] In the next several decades, the ice albedo feedback—whereby melting snow exposes more dark ground, which in turn absorbs heat and causes more snow to melt—will accelerate the rate of Arctic sea-ice melt. Projected increases in global air temperatures will diminish the extent of the snow cover and induce premature snow melt; this reduction in overall snow cover will itself exacerbate global warming.

The United Nations Environment Programme (UNEP) forecasts that the majority of middle latitudes will experience snow losses of as much as 60% to 80% in monthly maximum snow-water

Figure 8: Long-Term Weather Forecast Calls for Less Snow Cover

The United Nations Environment Programme forecasts that the majority of middle latitudes will experience snow losses of as much as 60% to 80% in monthly maximum snow-water equivalent by the end of the century.



Source: United Nations Environment Programme as of June 2007 equivalent by the end of the century.[6] The sharpest declines are expected to take place in Europe, while the UNEP model anticipates increases in the Canadian Arctic and Siberia (see Figure 8, page 5). Snow is a vital water resource for ecosystems and human activities, and changes in snow cover and snow extent in the decades to come are likely to have significant consequences.

GROUNDWATER ABSTRACTION

Approximately 2.5% of the earth's water is freshwater, of which 69% is in glaciers and the polar caps, 30% is fresh groundwater and 0.3% is in lakes and rivers. Total withdrawals of water account for 10% of renewable water, although in some countries this number is more than 100%.[7] Overextraction of water becomes an issue when more than 20% of renewable water is withdrawn, and by that standard the world is not facing a water crisis.

At the heart of the issue, however, is the uneven distribution of water resources. Many countries may have sufficient water on a national basis, but not regionally or locally, such as in China, the US, India and Spain. Countries may also have sufficient water but at the wrong time, such as in Trinidad, the Bahamas and the Cayman Islands. Long-distance water transport and storage are a priority in these instances, although there are frequently logistical, financial and/or political obstacles to such investments. The majority of nations that are deficient in renewable water rely on nonrenewable resources, which has led to problems in the form of overexploitation of surface water and groundwater. Such overexploitation can lead to a variety of problems, such as saline intrusion. In some cases, wells have been drilled so deep that the water becomes contaminated with radon from the earth's crust, which can cause severe health side effects that include lung cancer and birth defects. Such problems are typically localized, however, and can be resolved in the medium term via reverse-osmosis desalination of brackish water. Larger populations may be affected by a salinity crisis caused by overexploitation of the groundwater, but this is an issue that takes place over a 30-year period.

AGRICULTURE

The agriculture sector stands as the largest consumer of freshwater resources across the globe, accounting for more than 70% of global water withdrawals. GWI anticipates that the total land under irrigation (the main measurement of water use in agriculture) in the US will reach 290 million hectares by 2025—a 115% increase over 1996 levels.

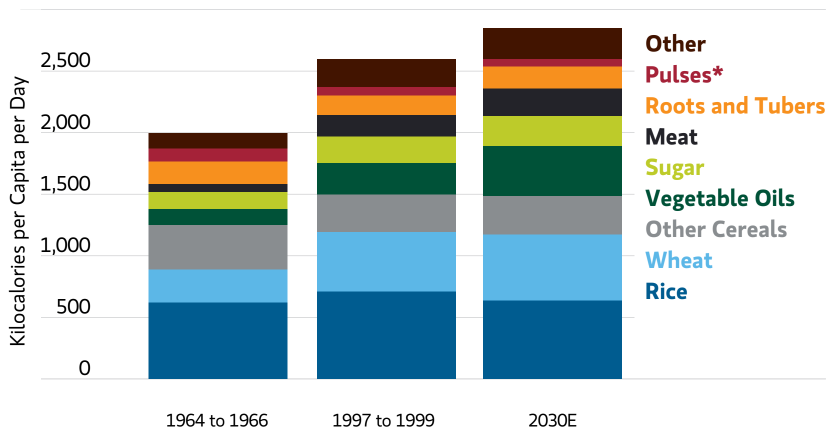
One of the most significant catalysts to agriculture's sustained growth and reliance on water is the steadily increasing global consumption of foods that are heavily dependent on water (see Figure 9). As a nation becomes more affluent, consumers increasingly prefer more water-intensive foods. The water needed to produce one kilo of meat is 10 times greater than the amount necessary to grow an equal serving of rice.

The utilization of modern agricultural methods has been a key contributor to the reduction of rural poverty throughout the world and, in many nations, governments continue to bolster the agricultural industry by subsidizing irrigation projects and promoting irrigation-friendly policies. The Indian government, for example, provides free electricity toward the extraction of groundwater. The proliferation of agriculture will continue to strain global water resources—a seemingly inevitable outcome in a world that continues to grow in both size and wealth.

The Millennium Development Goals, a framework of eight international development goals that all 193 United Nations (UN) member states and at least 23 international organizations have agreed to, aim to free people from extreme poverty and multiple deprivations by 2015. The volume of water for agriculture will need to increase in order to achieve the target of halving, between 1990 and 2015, the proportion of people who suffer from hunger (see Figure 10, page 7). To effectively decrease global famine, agricultural output—and therefore water use—must increase.

Figure 9: The Changing Composition of the Global Diet

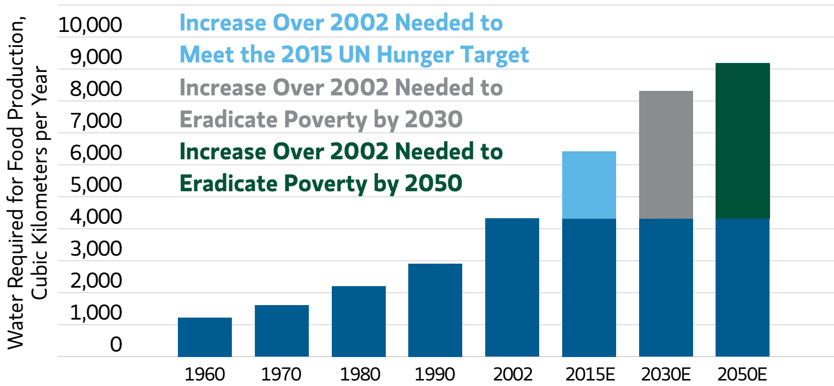
As they become more affluent, consumers increasingly prefer more water-intensive foods, such as meat, which, in turn, raises the demand for animal feed and, thereby, for water.



*The edible seeds of certain leguminous plants such as peas, beans or lentils
Source: United Nations Environment Programme as of February 2009

Figure 10: Changes in Global Water Consumption for Food Production

The volume of water for agriculture will need to increase in order to achieve the United Nations (UN) target of halving, between 1990 and 2015, the proportion of people who suffer from hunger.



Source: United Nations Environment Programme as of February 2009

URBANIZATION

In 1990, the world had 10 cities with populations of 10 million or more; six were in developing countries and four were in developed countries. By 2010, there were 21 cities of 10 million or more; 17 were in developing countries and four were in developed nations. The UN forecasts that by 2020 the world will have 27 cities of 10 million or more; 22 in developing countries and five in developed countries (see Figure 11).

Urbanization leads to increased water demand, for both household needs and services. Household needs, which include activities such as flushing a toilet, watering flowers or washing a car, increase daily per capita water needs by 80 to 250 liters. Service institutions, such as hospitals, restaurants and hotels, are also major consumers of water. Urbanization can cause the demand for water to increase five-fold beyond the "basic water requirement."[8] This increase does not include water used in power generation or other industrial activities that typically accompany urbanization.

More than half of the current global population resides in cities. As urban populations continue to grow, and as the standard of living of those dwelling in cities improves, there will be a need for more stringent environmental regulation, as well as increased capital expenditures for water and wastewater infrastructure.

Environmental-protection investment generates diminishing returns. While primary and secondary wastewater treatments are comparatively cheap processes and contribute to the quality of the environment, extracting nutrients, pharmaceutical by-products and endocrine disruptors from wastewater can be rather expensive and provide relatively minimal benefit. The outcome is that the world is encountering a spike in the amount of money needed for water and wastewater infrastructure, which subsequently garners more interest in technology. Although the water industry has traditionally comprised a series of individual domestic markets, it is becoming increasingly global in various segments. Advanced water and wastewater treatment, and several areas within the equipment supply chain, have become internationalized.

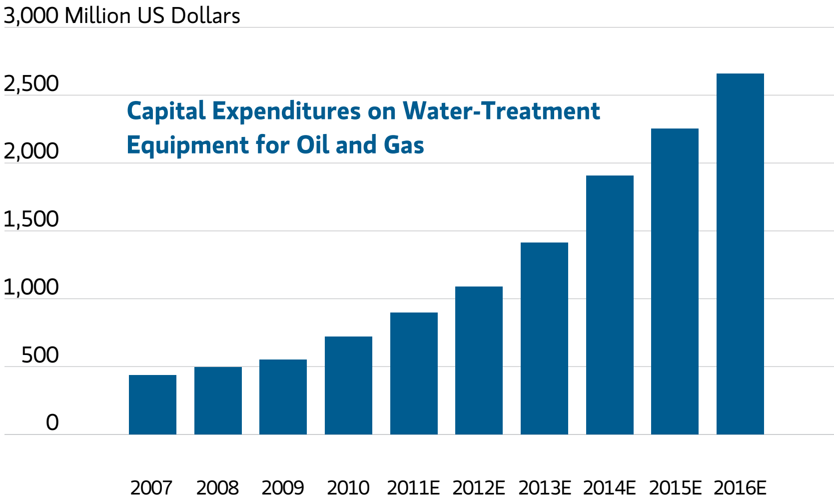
Figure 11: Urban Areas Forecast to Have at Least 10 Million Inhabitants by 2020

Rank	Urban Area	Country
1	Tokyo	Japan
2	Mumbai	India
3	Delhi	India
4	Dhaka	Bangladesh
5	Mexico City	Mexico
6	Sao Paulo	Brazil
7	Lagos	Nigeria
8	Jakarta	Indonesia
9	New York	US
10	Karachi	Pakistan
11	Kolkata	India
12	Buenos Aires	Argentina
13	Cairo	Egypt
14	Manila	Philippines
15	Los Angeles	US
16	Rio de Janeiro	Brazil
17	Istanbul	Turkey
18	Shanghai	China
19	Moscow	Russia
20	Osaka	Japan
21	Beijing	China
22	Lima	Peru
23	Paris	France
24	Tianjin	China
25	Lahore	Pakistan
26	Bogota	Colombia
27	Kinshasa	Congo

Source: United Nations as of 2011

Figure 12: Water Reuse Changes the Game for Oil and Gas

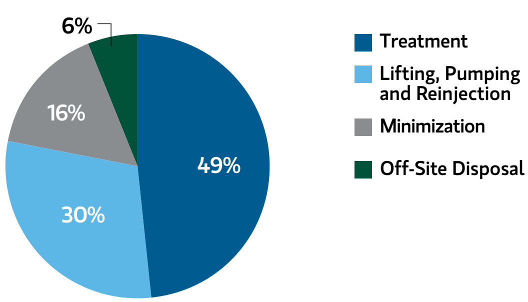
Land-based energy production results in "produced water," or water contaminated by the hydraulic-fracturing process. As a result, the energy industry is expected to boost spending in water-treatment equipment.



Source: Global Water Intelligence as of March 2010

Figure 13: Components of the $5 Billion North American Produced-Water Market

An increasingly popular option for disposing of produced water is on-site treatment, which has low fixed costs relative to other disposal options. The alternative to this process is to transport produced water to a treatment facility or disposal center.



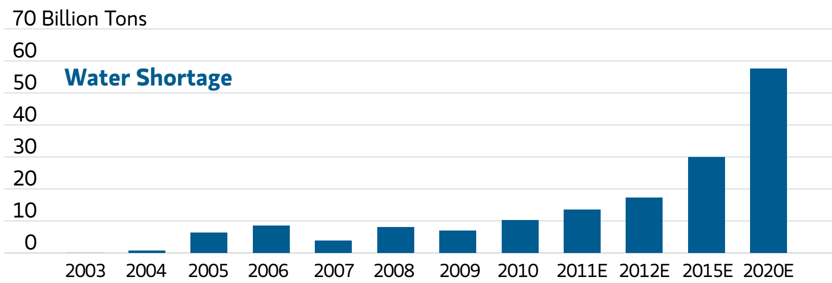
Note: Quantities may not equal 100% due to rounding.
Source: Citi Investment Research & Analysis as of May 2011

PRODUCED WATER

The increased prevalence of land-based natural-gas drilling and hydraulic fracturing throughout the US has generated much debate over environmentally friendly methods of disposing of "produced water." Produced water is water contaminated by the hydraulic-fracturing process that becomes infused with highly toxic chemicals. The disposal process for produced water has become one of the fastest-growing water subsectors, as natural-gas producers must take extra precaution and dedicate considerable resources to make certain that the contaminated water doesn't in any way mix with drinking-water sources (see Figure 12 and Figure 13). An increasingly popular option for disposing of produced water is "point-of-use treatment," whereby produced water is treated on-site. Point-of-use treatment has low fixed costs relative to other disposal options. The alternative to this process is to transport produced water to a treatment facility or disposal center via pipeline or truck.

Figure 14: Water Shortage in China Is Expected to Worsen

China's fast-paced economic growth has resulted in a water shortage that is forecast to worsen during the rest of this decade.



Source: Morgan Stanley Research as of November 2010

Figure 15: Rapid Growth for Residential Wastewater Operations in China

Substantial investment will be necessary to elevate China's wastewater-treatment industry to a level that is proportionate to its economic status. China's market for residential wastewater operations is forecast to rise to 40 billion renminbi in 2012 from 28 billion renminbi in 2010.

Source: Morgan Stanley Research as of November 2010

CHINA

Morgan Stanley Research forecasts that the water shortage in China is expected to worsen (see Figure 14). Substantial investment will be necessary to elevate China's wastewater-treatment industry to a level that is proportionate to its economic status.

In 2010, the Chinese government announced its intent to devote 3.1 trillion renminbi to the environmental-protection industry during the 12th Five-Year Plan versus the 1.3 trillion renminbi allocated in the 11th Five-Year Plan, generating an annual growth rate of approximately 15% to 20%. A study conducted at Tsinghua University concluded that investment in sewage-treatment facilities is projected to reach 153.97 billion renminbi throughout the 12th Five-Year Plan, up 35% from the 11th Five-Year Plan. As per the Chinese government's 12th Five-Year Plan, all cities and counties are expected to have 100% sewage-treatment capacity, versus the 75% of cities and 30% of counties that had sewage plants in 2009.[9] China's market for residential wastewater operations is forecast to rise to 40 billion renminbi in 2012 from 28 billion renminbi in 2010 (see Figure 15).

The Solution

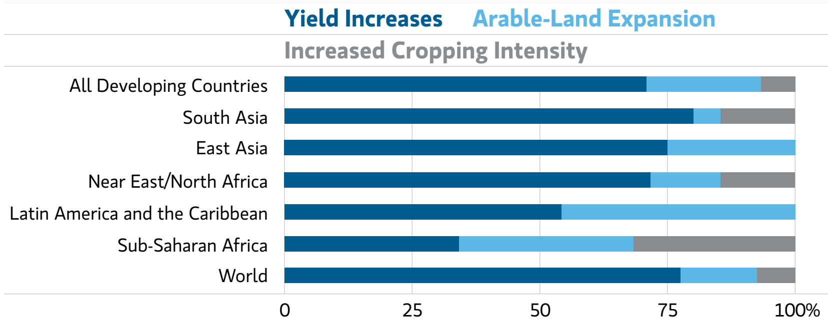
EFFICIENT IRRIGATION

Approximately 70% of all water is used for agriculture, and our ability to expand agricultural output to sustain the growing global population is restricted in part by the limited supply of freshwater. According to the Food and Agriculture Organization (FAO), approximately 20% of the increase in crops produced by 2050 will be attributed to newly irrigated lands, while 80% will have to come from increases in crop yields. Land that is fit for growing crops is finite and the areas that have yet to be cultivated require costly infrastructure build-outs. The most effective long-term solution will be creating and enhancing agricultural technologies to produce more "crop per drop" (see Figure 16 and Figure 17). As the world's water supplies continue to be strained by growing populations and as arable land per capita continues to decline, agricultural efficiency will become a major focus of policymakers and investors alike.

There are several irrigation techniques that are capable of effectively producing crops with relatively minimal amounts of water. In most developing economies, the overwhelming source of irrigation is flooding fields. Flooding is only about 35% efficient; 65% of the water evaporates before it reaches the crops. By contrast, sprinklers are 75% efficient. Drip irrigation is 85% efficient and widely accepted as one of the most effective water-saving irrigation systems. This process gradually applies water to the crop's roots through a system of valves, pipes, tubing and emitters. Alternative methods that are capable of increasing crop yields with less water include center-pivot sprinkler irrigation, advanced fertilizers and watering-schedule controls that account for weather conditions.

Figure 16: Share of Crop Production Increases, 1961 to 1999

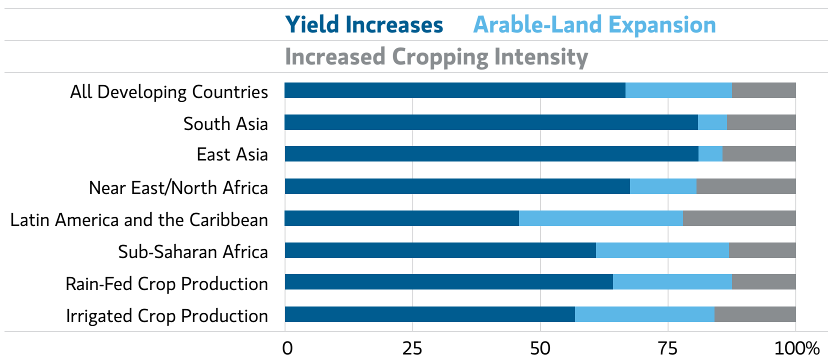
Between 1961 and 1999, nearly 80% of the increase in world crop production came through increasing yield on existing land.



Source: United Nations Environment Programme, GRID-Arendal as of February 2009

Figure 17: Projected Sources of Increases, 1997/1999 to 2030

Looking ahead, increases in crop production will need to come from creating and enhancing agricultural technologies to produce more "crop per drop."



Source: United Nations Environment Programme, GRID-Arendal as of February 2009

The FAO expects global irrigation water withdrawal to increase by approximately 11% to 2,906 cubic kilometers per year in 2050, up from the current 2,620 cubic kilometers per year. Output from irrigated lands globally is set to increase to 3,424 trillion kilocalories in 2025 and 5,420 trillion kilocalories in 2050 from 2,544 trillion kilocalories in 2010 (see Figure 18, page 11). Global irrigation water withdrawals are forecast to rise by 14% in the developing countries, offset by a decline of more than 2% in the developed countries.

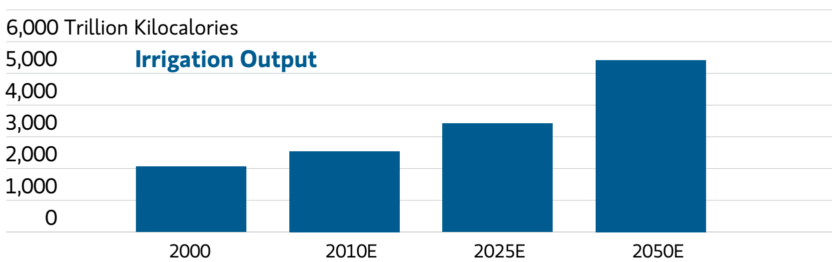
China and India stand out as having ample opportunity to boost crop yields, as both governments have recently demonstrated a commitment to increasing agricultural productivity and efficiency. At the Fifth World Water Forum in 2009, China's minister of water resources underscored China's goal to increase the nation's irrigated area by 10% by 2020, as well as restore 260 large-scale irrigation and drainage pumping centers within three to five years. In 2008, India's minister of agriculture declared his goal to bring 17 million hectares under efficient irrigation (12 million hectares under microirrigation and 5 million hectares under sprinkler irrigation) by 2012; the Indian Planning Commission predicts that water supply and irrigation capital expenditures will experience a subsequent compound annual growth rate of 19% to reach this goal.[10]

AGRI-BIOTECH

Biotechnology companies recognize that demand for drought-tolerant crops will continue to rise as global climate change forms a world that is both warmer and drier. These companies are utilizing both conventional breeding and genetic engineering to develop crop varieties that can effectively maintain their output in regions stricken with drought (see Figure 19). For example, researchers are engaged in various phases of testing for corn strands that have been genetically manipulated to retain yield stability in the driest of environments. Already one particular gene that is undergoing testing has demonstrated encouraging yield advantage when water is limited, and further testing has found the gene to be compositionally equivalent to conventional corn.

Figure 18: Forecast Growth in Irrigation Output

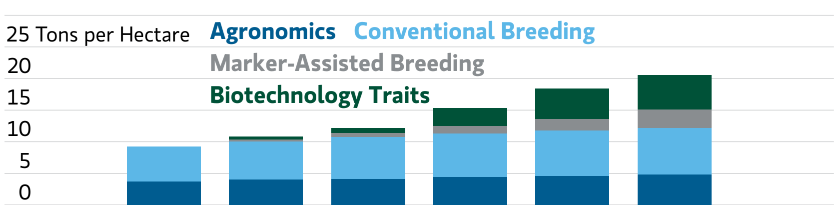
Thanks to improvements in irrigation technology, global output from irrigated lands is forecast to more than double by 2050 on just 11% more water, according to the United Nations Food and Agricultural Administration.



Source: United Nations Food and Agriculture Administration as of 2003

Figure 19: Composition of the Corn Yield

Agricultural companies are utilizing both conventional breeding and genetic engineering to develop crops that can maintain their output in drought-stricken regions.



Source: Monsanto Company as of January 2009

WASTEWATER TREATMENT

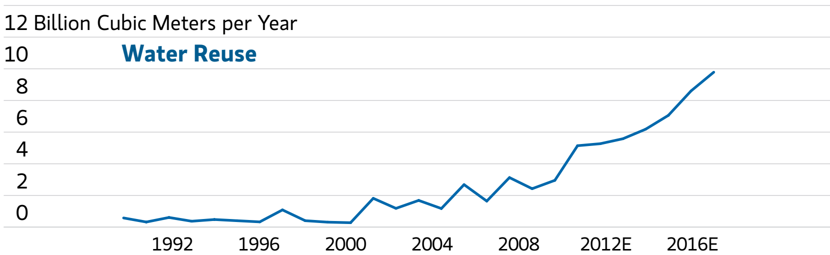
Treated wastewater costs about a third less than desalination. In addition to tertiary and advanced reuse, a significant portion of water reuse involves treatment that does not go beyond the secondary level. Primary treatment involves temporarily holding sewage so that heavy solids settle to the bottom while oil, grease and lighter solids float to the surface. Secondary treatment then removes dissolved and suspended biological matter. Tertiary treatment then allows discharge into a highly sensitive or fragile ecosystem. This being the case, the capacity of water-reuse facilities that offer no more than secondary treatment is expected to increase to 36 million cubic meters per day in 2016 from 22 million cubic meters per day in 2008, and total investment in water reuse is forecast to rise to 9.8 billion cubic meters per year in 2016 from 5.1 billion cubic meters per year in 2010 (see Figure 20).[11]

Advanced wastewater treatment means that sewage can be viewed as a resource with a number of possible uses: (1) agricultural irrigation, because wastewater flows are typically more reliable than those from freshwater sources and are rich in nutrients for the cultivation of high-value crops; (2) urban landscaping; (3) industrial cooling and processing; and (4) indirect potable water production, such as groundwater recharge.

The water-treatment process known as ultraviolet (UV) disinfection is gaining popularity throughout the water industry as a cost-effective and superior alternative to chlorine disinfection. Recent technological developments within the UV sector have made treatment both affordable and simple. In this purification process, exposure to UV light effectively changes the DNA of any harmful microbes, thus sterilizing the cell. The $500 million UV-treatment industry is expanding rapidly (see Figure 21). BCC Research estimates that the market will grow at an annual rate of approximately 40% during the next five years. The Environmental Protection Agency now requires certain drinking-water sources to undergo UV disinfection because of its ability to neutralize various parasitic diseases that are impervious to chlorine treatment. In 2012, New York City is expected to break ground on the world's largest UV disinfection treatment facility.

Figure 20: Investments in Water-Reuse Plants

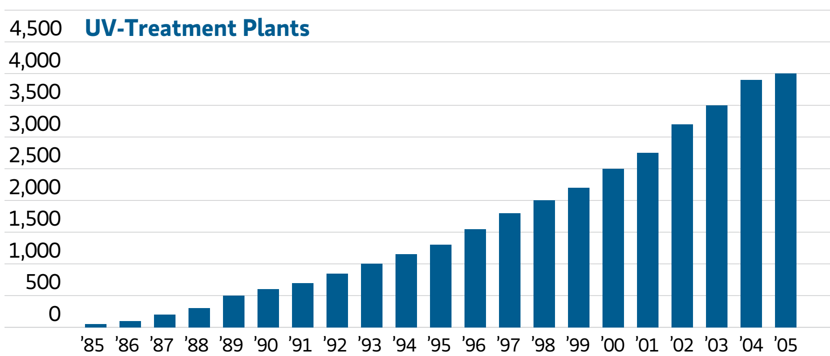
Investment in water-reuse plants is growing because treated wastewater costs about a third less than desalinated water. The output from water-reuse facilities is forecast to reach 9.8 billion cubic meters in 2016, up from 5.1 billion cubic meters in 2010.



Source: Global Water Intelligence as of March 2010

Figure 21: North American Wastewater-Treatment Plants Using UV Technology

The water-treatment process known as ultraviolet (UV) disinfection is gaining popularity as a cost-effective and superior alternative to chlorine disinfection.



Source: Citi Investment Research & Analysis as of May 2011

DESALINATION

There are currently two methods for desalination: Either water can be boiled and gradually evaporated in a process known as thermal desalination, or it can undergo a membrane-filtration method known as reverse osmosis, in which the water is pushed through a fine membrane that separates the water molecules from the salt ions. GWI says that thermal desalination will continue to be used in regions where energy is inexpensive and plentiful, such as the Middle East. The consulting firm also estimates that investments in desalination plants with membrane technology will grow to $4.7 billion in 2016 from $3.3 billion in 2010—a 6% compound annual growth rate versus just 1% for thermal desalination (see Figure 22).

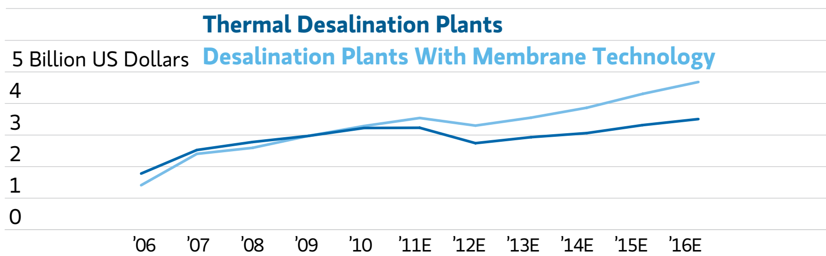
During the past several decades, the desalination industry has had remarkable success in lowering its costs through technological innovation. In thermal desalination, a large portion of recent progress can be attributed to economies of scale. The membrane segment of the desalination industry has utilized technological advancements to create energy-recovery devices and cheaper, yet more efficient, membranes, which have resulted in impressive cost reduction for desalinated water.

Figure 23 shows water prices for reverse-osmosis projects, which are arranged by contract date. The first eight bars on the chart would be familiar to anyone who goes to desalination conferences—they are the most common illustration of the falling cost of desalination. The remaining bars appear to tell a different, more complicated story. Innovation in desalination technology is continuing. As the cost of the desalination process falls, other costs such as civil engineering and site costs have a greater influence on the overall cost of water. This is particularly true of desalination projects on the California coast, where costs for labor, permits, real estate and professional services are very high.

The desalination industry's ability to significantly drive down costs while simultaneously bolstering its technology will translate into substantial future growth. GWI predicts that contracted desalination capacity will rise to 130 million cubic meters per day in 2016 from 68 million cubic meters per day in 2009. The mounting effort to drive down the cost of desalination has resulted in the emergence of several promising new technologies.

Figure 22: Investments in Desalination Plants

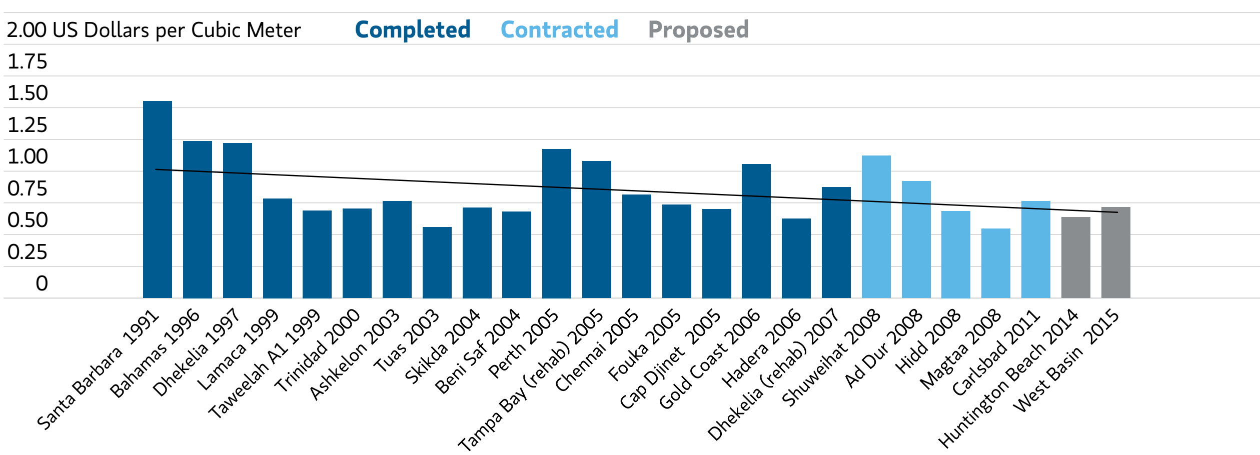
Thermal desalination plants are mainly in regions where energy is inexpensive, such as the Middle East. Costs for membrane-based desalination plants are dropping because of more efficient membranes and energy-recovery devices.



Source: Global Water Intelligence as of March 2010

Figure 23: Water Prices for Reverse-Osmosis Projects

Innovation drives down the cost of the desalination projects that use reverse osmosis. As the cost of desalination falls, costs such as engineering and site preparation have a greater influence on the overall cost.



Source: Global Water Intelligence as of March 2010

NEW DESALINATION TECHNIQUES

Forward Osmosis

Since water molecules naturally flow from fresher solutions to saltier ones, reverse osmosis uses pressure to force water molecules to go against that tendency through membranes that filter the water. In contrast, forward osmosis (FO) uses a "draw solution" that is saltier than seawater. Without need for any energy, the water molecules in seawater flow across a porous membrane and into the draw solution, leaving the sea salt behind. Because the process doesn't require any pumping, it generally consumes very little energy. These compounds then vaporize at lower temperatures than those required for thermal desalination (212°F). Unlike reverse-osmosis treatment, FO does not need to be forced through a membrane at high levels of pressure, which translates into substantial cost savings; FO requires only 10% as much electricity as reverse osmosis and does not have to rely on the costly pipes that are specially constructed to tolerate high pressures.[12]

In 2007, researchers at Yale University built a pilot plant to demonstrate an FO desalination process that uses osmotic pressure, rather than hydraulic pressure or thermal evaporation, to separate freshwater from seawater or brackish water. In February 2009, a company built around the research from Yale announced that it had received $10 million in venture-capital funding to commercialize its novel desalination technique. The company's solution needs only 122°F to burn off salts and leave behind pure water rather than the much higher temperatures required for thermal desalination. *Bloomberg Businessweek* (March 10, 2011) reported that the company plans to start taking orders in late 2011.

Carbon Nanotubes

Leading chemical- and environmental-science researchers are in the midst of refining a desalination technology that employs carbon nanotubes in the membrane-distillation process. Carbon nanotubes, which are essentially atom-thin carbon sheets that have been shaped into cylinders, can be immobilized in membrane pores to construct a filtration system that is superior to typical reverse-osmosis membranes in that they are approximately 20 times more water permeable and can treat water at a relatively low temperature, higher flow rate and higher salt concentration.

The September 2010 *Journal of Physical Chemistry* reported that Professor Somenath Mitra of the New Jersey Institute of Technology had developed a membrane incorporating carbon nanotubes that could lead to a faster and more energy-efficient method of water desalination. Mitra's new material reportedly results in much greater vapor permeation while keeping liquid water from clogging the pores, and it allows for higher flow rates while requiring lower temperatures. As compared with a regular membrane, it demonstrated the same level of salt reduction at a temperature that was cooler by 20°C and at a flow rate that was six times greater.

Biomimetic Membranes

Scientists at the University of New Mexico and Sandia National Laboratories are working on revolutionizing the desalination industry through the creation of biomimetic membranes for water-filtration treatment. Biomimetic membranes seek to mimic the structure and water-transport processes of living cell membranes, which could provide an incredibly efficient and natural filtration system. According to the University of New Mexico, "The technology uses an atomic layer deposition (ALD) process, a thin-film deposition technique on an atomic scale that sequentially applies layers of chemicals to the surface of a substrate to produce a thin film. The nanoporous material has twice the efficiency of an RO [reverse osmosis] membrane because it has high salt rejection and improved water flux (the rate at which water permeates a membrane)."[13]

Figure 24: Saving Water Through Land Investments

Many nations save water resources by making investments that allow them to outsource water-intensive crops. This table shows where countries are investing and for which crops.

Investor Country	Target Country	Area (hectares)	Crop or Aim of Project
Austria	Ethiopia	50,000	Biofuel
Bahrain	Philippines, Turkey, UAE	10,000	Agro-Fishery
Belgium	Kenya	42,000	Sugar Cane
Canada	Kenya, Mozambique, Ghana	293,000	Biofuel
China	Dem. Rep. Congo, Mozambique, Tanzania, Zambia, Philippines, Cameroon, Sierra Leone	6,512,300	Biofuel, Rice, Sugar Cane, Maize
Egypt	Sudan	526,000	Wheat, Maize, Sugar Beets
Germany	Ethiopia	13,000	Biofuel
India	Ethiopia, Sierra Leone	348,258	Flower, Sugar, Maize, Rice, Vegetables, Palm Oil
Iran	Sierra Leone	10,117	Biofuel, Lemon Grass
Israel	Ghana, Ethiopia	202,000	Biofuel
Italy	Ghana, Mozambique	20,000	Biofuel
Japan	Brazil, Kenya	100,000	Soybeans, Biofuel
Jordan	Sudan	25,000	Livestock, Crops
Kuwait	Kenya, Sudan	170,000	Rice
Libya	Mali, Ukraine, Liberia	364,000	Rice
Luxembourg	Sierra Leone	62,475	Biofuel, Palm Oil, Rubber
Norway	Ghana	427,660	Biofuel
Portugal	Mozambique, Sierra Leone	151,000	Biofuel, Rice, Pineapple, Cassava, Vegetables
Qatar	Philippines, Sudan, Kenya	140,000	Fruit, Vegetables
Republic of Korea	Russia, Sudan, Indonesia,	715,000	Wheat, Palm Oil
Saudi Arabia	Sudan, Tanzania, Indonesia, Ethiopia, Egypt	5,520,000	Rice, Wheat, Vegetables, Barley, Animal Feed
South Africa	Congo (Brazzaville), Benin	80,000	Livestock, Rice, Vegetables
Switzerland	Sierra Leone	26,000	Sugar Cane
UAE	Pakistan, Sudan, Ethiopia	707,000	Corn, Alfalfa, Wheat, Potatoes, Beans
UK	Ethiopia, Angola, Ghana, Madagascar, Mozambique, Ukraine, Sierra Leone	1,046,348	Biofuel
US	Brazil, Sudan, Ukraine, Ethiopia	690,000	Sugar Cane (biofuel)
Vietnam	Cambodia, Laos	200,000	Rice, Rubber

Source: United Nations Environment Programme as of July 2011

VIRTUAL WATER

A 2011 United Nations Educational, Scientific and Cultural Organization study found that one-fifth of the global water footprint (from 1996 to 1995) was related to production for exports, largely agricultural, rather than domestic consumption.[14] Large international virtual-water flows and their associated national water savings and external water dependencies highlight the point that the issue of local water scarcity needs to be considered from a global context.

Many nations save water resources by importing products that are water intensive and exporting those that are less so (see Figure 24). This process can imply global water savings if the flow is from nations with high to low water productivity. Between 1997 and 2001, 1,605 billion cubic meters per year would have been required by the importing countries if all imported agricultural products were produced domestically; however, these products were produced with only 1,253 billion cubic meters per year in the exporting countries.[15]

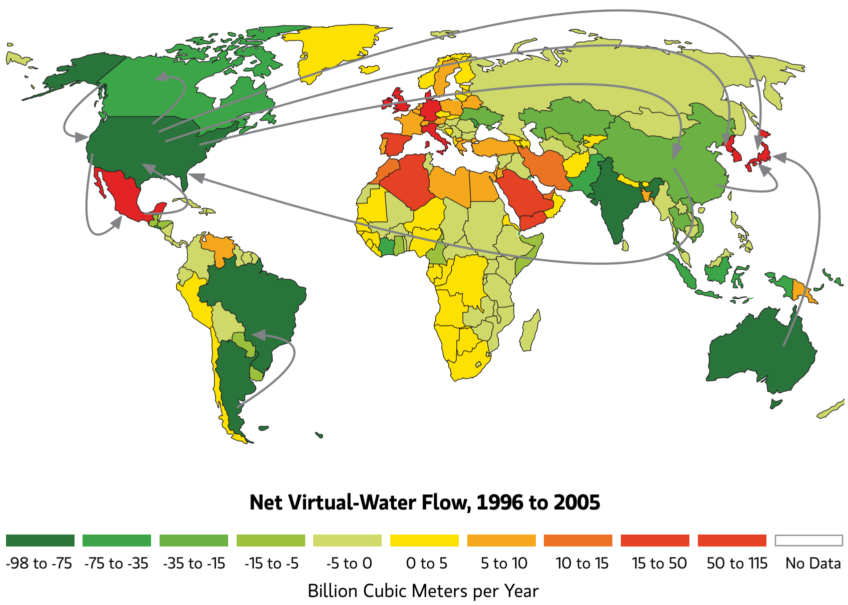
Nations are divided in their ability to use science to support agricultural productivity and food security. Developed countries spend $2.16 on agricultural research and development (R&D) for every $100 of agricultural output, compared with $0.55 in the developing countries. Agricultural R&D spending in developing countries grew to $4.4 billion in 2000 from $3.7 billion in 1991. Such spending was largely driven by Asia, which represents 42% of total agricultural R&D spending in developing nations (China and India account for 18% and 10%, respectively). Despite Africa's large size, its share in R&D spending is 13%; Latin America's is 33%.[16]

Figure 25 depicts the virtual-water balance per country. The key for Figure 25 indicates which countries—and to what degree—have a negative balance, or a net virtual-water export, and which have a positive balance, or net-water import. The biggest virtual-water net exporters are in North America and South America (US, Canada, Brazil, Argentina), Southern Asia (India, Pakistan, Indonesia, Thailand) and Australia. The biggest virtual-water net importers are North Africa and the Middle East, Mexico, Europe, Japan and South Korea.

The 2008 food crisis accelerated farmland transactions (see Figure 26); governments have moved into large-scale agriculture in their expectation of gains from food crops, biofuels and environmental services. China, the Gulf States, Japan, India, South Korea, Libya and Egypt are purchasing farmland in Ethiopia, Mali, Sudan, Madagascar and Mozambique in Africa; the Philippines, Indonesia, Laos, Thailand, Vietnam, Cambodia

Figure 25: How Virtual Water Flows

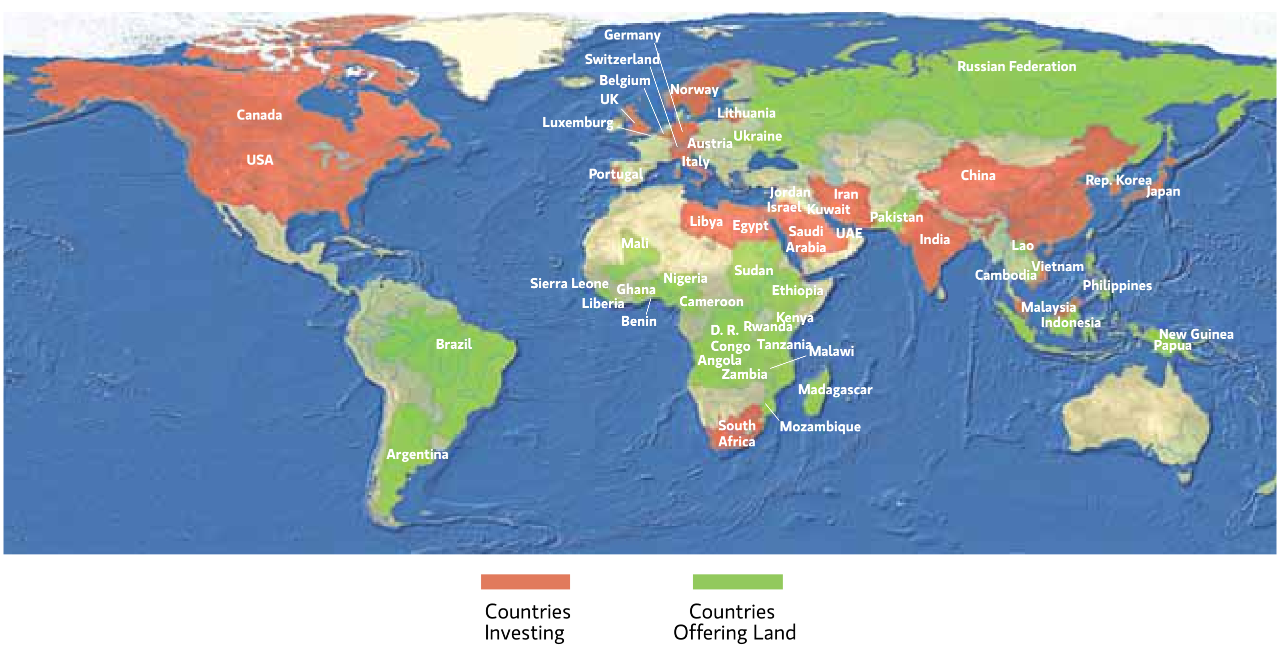
Countries in green are net virtual-water exporters. Countries in yellow or red are net virtual-water importers. The arrows indicate the flow patterns.



Source: United Nations Educational, Scientific and Cultural Organization as of May 2011

Figure 26: Investor and Target Countries in Overseas Land Investment for Agricultural Production

Since the 2008 global food crisis, governments have moved into cross-border agriculture in expectation of gains from food crops, biofuels and environmental services.



Source: United Nations Environment Programme as of July 2011 and Pakistan in South Asia; Brazil and Argentina in South America; and the Ukraine in Eastern Europe.

Indian companies are buying overseas land, primarily in Africa, to grow agricultural products that can be exported to large markets. Africa has 807 million hectares of cultivable land, and 197 million hectares are currently under cultivation. More than 80 Indian companies have invested $2.4 billion in purchasing plantations in eastern Africa to grow food for India's domestic markets.[17]

China is also investing in agriculture overseas. Northeast China's Beidahuang Group intends to enter into an agricultural joint venture with Argentina's Rio Negro Province. According to the Argentine government, China's state-owned farmland investment and development company, which is China's top grain producer, is planting crops in the Patagonian province and paying low rent in exchange for developing unused land. The Beidahuang Group's Argentina agricultural investment project will include advanced irrigation, power-generation facilities and port-infrastructure investments. Although Argentina has high-quality land with an ideal climate, the technology level is lacking. This synergy of technical expertise from China and land resources from Argentina makes for a partnership that should significantly benefit both parties involved.

A Developing Story

Water may turn out to be the critical commodity story of the 21st century as declining supply and increasing demand combine to create a "perfect storm." To address the challenges, the global water industry is expected to undergo a fundamental transformation. Businesses will need to invest in new technologies, while utilities will need to devote greater resources to water infrastructure. Investment growth in the sector will be affected by the changing financial models in the municipal water sector, where budgetary constraints will limit the role traditionally played by municipalities. The key to profiting from the growth in the sector will be to understand the technological, climactic, governmental and population trends affecting the water industry. The winners will be those who can grasp those trends and discover the underlying opportunities.

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