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Goldman Sachs

Sustainable Growth: Taking a Deep Dive into Water

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Water could be a constraint on growth

The world's freshwater resources are unevenly distributed around the planet: over 60% of the Earth's freshwater supply is found in just 10 countries. Severe water stress affects 3 billion people, two-thirds of whom reside in the BRICs. Water needs are quickly increasing in emerging economies such as China and India, which together account for nearly 40% of global population and a third of global water demand. Moreover, water resources in many developing countries are becoming heavily polluted and unsuitable for human use. Inadequate water resources could be an impediment to growth as developing nations face rapidly growing demand for food and energy.

Growing energy demand drives water use

Energy needs are increasing rapidly in emerging economies and the fuel mix used has a direct impact on water resources. Currently, close to a third of global energy demand is met by oil, an extremely water-intensive fuel source. Natural gas is a growing alternative to oil, led by the "shale revolution" in the United States. The extraction of unconventional gas is water-intensive and an adequate water supply is a critical ingredient in shale production. US shale gas development has been aided by the country's abundant water resources. In contrast, inadequate water supplies could be a constraint for prospective shale-producing countries like China and Mexico.

Virtual water trade to feed the expanding middle class

The expansion of the middle class in developing countries is expected to shift dietary preferences from predominantly plant-based foods to more water-intensive meat and dairy products. To manage these dietary changes, many water-scarce nations have engaged in "virtual water" trade, reducing domestic agricultural water use by importing water-intensive products from water-rich countries.

Market opportunities in water risk mitigation

Many water-scarce countries have adopted strategies to mitigate water risks; for example, the large-scale desalination plants in the Middle East and Israel's treatment and reuse of wastewater for irrigation. The global water industry, which includes sectors like desalination and water-efficiency technologies, is estimated to total over $300 billion.

Table of Contents

Exhibits

Executive Summary

Water: a critical resource, unevenly distributed

The world's freshwater resources are unevenly distributed around the planet. Over 60% of the Earth's accessible freshwater supply is found in just 10 countries, including Brazil (13% of global resources), Russia (10%), Canada (7%) and the United States (7%). This imbalance is further evident at the per-capita level. For example, China has roughly the same amount of water as the United States, but it also has four times the US population.

As a result of the uneven distribution, an estimated 2.8 billion people currently live in areas under severe water stress.[1] A large percentage of the affected population resides in developing countries; in fact, close to two-thirds live in the BRICs (Brazil, Russia, India and China). Moreover, water needs are rapidly increasing in emerging economies such as China and India, which together account for nearly 40% of global population and a third of worldwide water demand. For instance, India alone accounted for more than 30% of the increase in global water withdrawals[2] over the past 15 years.

Poor management of resources add to water challenges

The pollution and contamination of water resources pose additional constraints on supply. This is particularly a concern in many developing nations given the lack of adequate wastewater treatment facilities. According to the UN, roughly 90% of all wastewater in developing countries is discharged untreated, directly into the sea or rivers. Moreover, the rapid rates of urbanization in many emerging economies have outpaced the construction of sanitation facilities. Further, the emphasis on economic growth has often taken priority to other issues such as maintaining water quality near industrial sites.

Scientists believe climate change will increase the frequency of extreme weather events and exacerbate the uneven distribution of the global water supply. Arid regions will likely be the most impacted as water resources become increasingly scarce.

Competing for water: the water-energy nexus…

Inadequate water resources could be an impediment to growth as developing nations face growing demand for food and energy. Globally, average electricity generation per capita is projected to almost double by 2050.[3] Water plays a critical role in major steps of energy production: extraction, refining and electricity generation. Thus, the fuel mix used to meet the rising energy demand has a direct impact on water resources.

Close to a third of global energy needs is currently met by oil, one of the most water-intensive fuels. The increasing production of unconventional oils (such as heavy oils and oil sands) has significant water implications, as these sources are estimated to consume 2.5 to 4 times more water than conventional oil.

Natural gas is expected to play a larger role in the global fuel mix, led by the "shale revolution" in the United States. Because shale gas extraction is relatively water-intensive,

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[1] The definition used by the OECD for water stress refers to water withdrawals as a percentage of total renewable resource. Below 10% is considered no stress, 10-20% is low stress, 20-40% is medium stress and above 40% is severe stress.

[2] Water *withdrawals* refer to the amount of water removed from the source, a portion of which can potentially be reused. In contrast, water *consumption* refers to the amount that is expended and not available for reuse. See Appendix C for a more detailed explanation.

[3] World Energy Council.

an adequate water supply is a critical ingredient in shale production. Shale development in countries like Canada and the United States has been aided by abundant domestic water resources. In contrast, some regions in China that are believed to contain significant amounts of shale gas deposits are located in water-scarce areas.

Water also plays an important role in power generation, where it is used in the cooling process for thermoelectric plants. When water is withdrawn for cooling power plants, a sizable amount can be reused again (though the quality may vary). The reusable quantity depends on the fuel source and the type of cooling technology employed. Among thermal sources, nuclear energy withdraws the largest amount of cooling water, mainly to maintain the temperature at the reactor core, though a sizable amount is typically reused. Renewable sources of electricity, such as wind and solar photovoltaic (PV) cells, generally require small amounts of water, mostly for cleaning.

…and agriculture to feed the growing population

To feed the growing world population (projected to increase 30% by 2050), the agricultural sector, currently 70% of global withdrawals, will continue to be a major user of water resources. The expansion of the middle class in developing nations has a large impact on agricultural water use. The rise in incomes typically results in a shift in dietary preferences from predominantly plant-based diets to more water-intensive dairy and meat products.

To meet these dietary changes, many countries, particularly those in water-scarce regions, have engaged in "virtual water" trade. Virtual water refers to the water that is used in the production of a good. For example, when a country imports one ton of wheat, it is importing virtual water—that is, the water needed to produce the crop. Virtual water trade has been suggested as a way to alleviate the uneven distribution of water by allowing for the transfer of water resources from water-rich nations to water-scarce countries. It could also allow for greater efficiency of water use as virtual water flows from relatively more-efficient countries to less-efficient ones. For example, China imports soy-based products mainly from three countries, Brazil, the United States and Argentina, which are able to produce soy with less water than domestic production in China.

Water-stressed countries seek to address supply challenges

The number of people impacted by severe water stress is projected to reach 4 billion by 2030,[4] roughly half the global population. Many countries, especially those in water-scarce geographies, have adopted strategies to manage water risk, such as the large-scale desalination plants in the Middle East and Israel's treatment and reuse of wastewater for irrigation (over 80% of household wastewater is treated and reused for irrigation in Israel, about four times the next-highest rate in the world). As countries seek to address mounting water challenges, companies have seized on the business opportunity to provide solutions. The global water industry, which is estimated to total over $300 billion,[5] includes sectors like desalination (converting saline water into potable water), wastewater treatment (recycling wastewater to be reused) and water-efficiency technologies.

Government efforts to contain demand are complicated given the heavily subsidized water costs (particularly for agricultural use) in many countries. The low price of water in most regions of the world makes it challenging to incentivize users, especially those in relatively water-rich regions, to improve efficiency.

[4] OECD.

[5] Global Water Intelligence estimates a global market size of $316 billion.

Water: a critical resource, unevenly distributed

The world's water resources are distributed unevenly around the planet: over 60% of the global supply is found in 10 countries.

The imbalance is more strikingly evident at the per capita level.

The uneven global distribution

The world's freshwater resources are distributed unevenly around the planet. North America, for example, has an abundance of freshwater, in sharp contrast to regions at the other end of the spectrum such as the arid Middle East. In fact, over 60% of the world's freshwater supply is found in 10 countries (see Exhibit 1), notably Brazil (13% of global resources), Russia (10%), Canada (7%) and the United States (7%).

The imbalance is further evident on a per-capita basis (see Exhibit 2). For instance, Canada's abundance of freshwater resources and its relatively sparse population mean the country has close to 85,000m^3 of freshwater per person.[6] In contrast, China, with 20% of the global population, has just roughly 2,000m^3 of freshwater per capita, less than 3% of Canada's per capita availability.

As a result of the uneven global distribution, nearly 3 billion people currently live in areas under severe water stress.[7] A large portion of the affected population resides in developing countries: close to two-thirds live in the BRICs (Brazil, Russia, India and China). An imbalanced *local* distribution of resources adds to water strains. For example, some of the major cities in China, including Beijing, are located in drought-prone regions (see Box on disparities at the local level).

With water needs growing rapidly in emerging economies, the global number of those living under severe water stress is projected to increase by an additional one billion people by 2030 to total 3.9 billion. (See Appendix B for further discussion on populations impacted by water stress.)

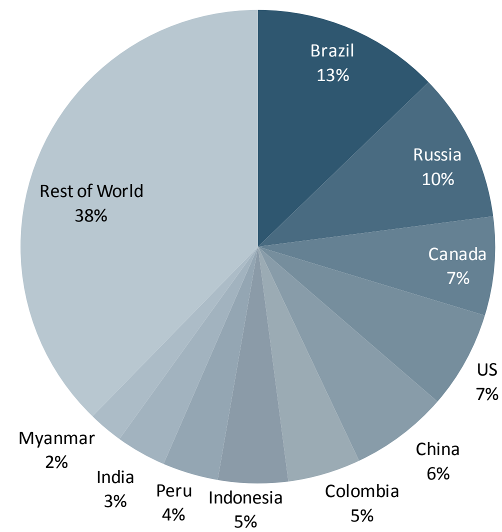
Disparities at the Local Level

Large disparities also exist within a country's borders. For example, the United States is relatively water abundant in absolute terms but there are significant regional differences: the Southwest region of the country is arid and drought-prone, while the Northeast and Midwest areas have more precipitation and access to the Great Lakes (which make up the largest surface freshwater system on Earth). Another example is China: precipitation and groundwater supplies are concentrated in the South, whereas the Northern part of the country is drought-prone. The Chinese government is attempting to address this uneven distribution through the ambitious $60 billion South-to-North water transfer project, which aims to divert water from the Yangtze River to drier regions in the North, where major cities like Beijing and Tianjin are located. Construction for the project is ongoing, with one route scheduled to begin transferring water starting in 2014. It has been a controversial project due to its environmental impact in some areas.

[6] Per capita freshwater resources include internal renewable resources such as river flows and groundwater from rainfall (World Bank definition). See Appendix A for further discussion on global water resources.

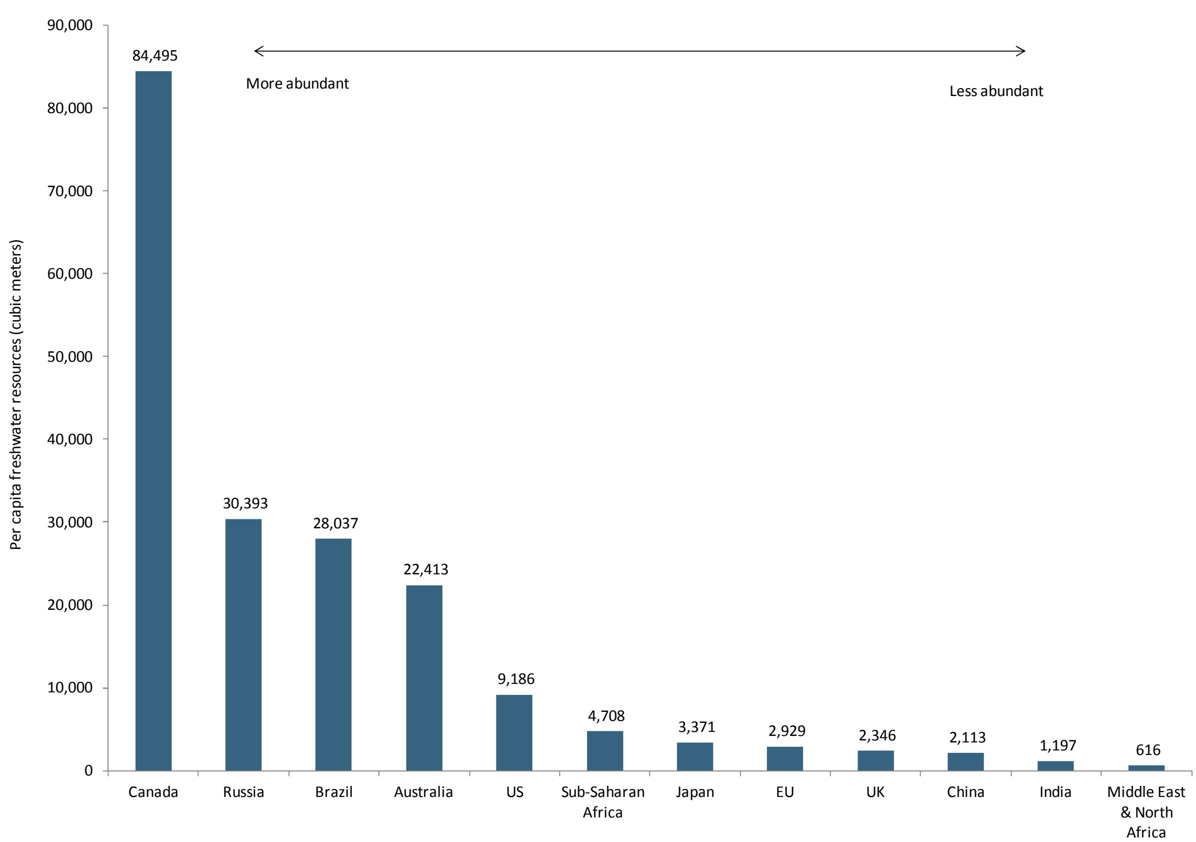
[7] The definition used by the OECD for water stress refers to water withdrawals as a percentage of total renewable resource. Below 10% is considered no stress, 10-20% is low stress, 20-40% is medium stress and above 40% is severe stress.

Exhibit 1: Ten countries possess over 60% of the world's freshwater supply
Geographic breakdown of global freshwater resources, 2009 data



Source: World Bank.

Exhibit 2: A wide disparity in per capita distribution
Per capita freshwater resources, 2009 data



Source: World Bank.

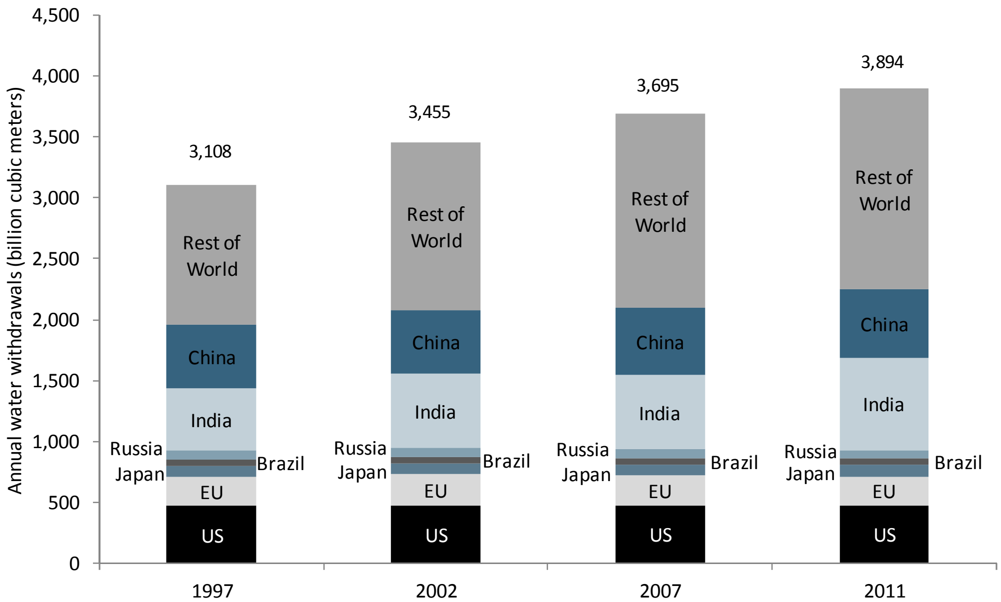
The rising water needs in developing economies intensify scarcity concerns.

Growing demand contributes to water stress

Water use in developing countries has increased rapidly over the past fifteen years. Since 1997, water withdrawals have increased by 81% in Vietnam, 52% in India and 43% in Mexico. See Exhibit 4. Today, China and India account for a third of global water demand (see Exhibit 5). In contrast, water withdrawals in developed economies like the United States and Japan have stayed relatively constant.

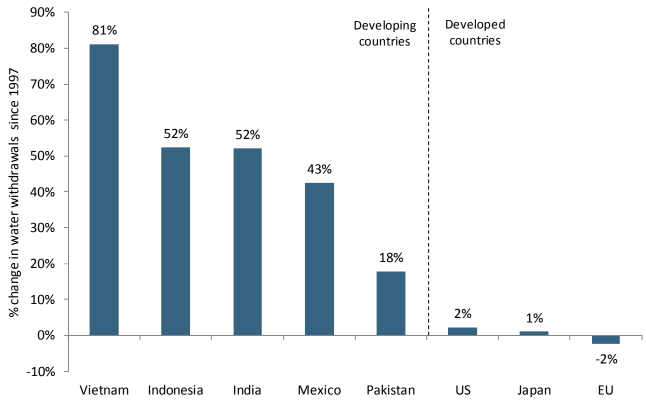
One key distinction is between water *withdrawals* versus *consumption*: water withdrawals refer to the amount of water removed from the source, a portion of which can potentially be reused. This is different from water consumption, which refers to the amount that is expended and not available for reuse. International data tend to focus on withdrawals. (See Appendix C for a more detailed discussion.)

Exhibit 3: Developing economies have been major drivers of global water demand
Breakdown of global freshwater withdrawals



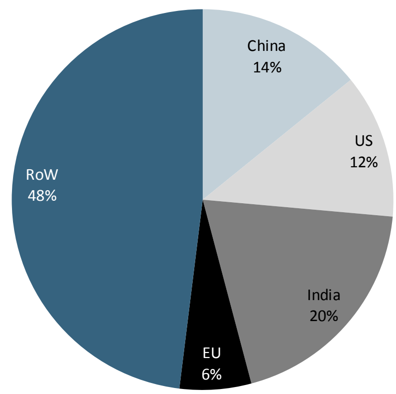
Source: World Bank.

Exhibit 4: Water withdrawals have increased rapidly in developing countries
Percentage change in total water withdrawals in selected nations, between 1997 and 2011



Source: World Bank.

Exhibit 5: China and India account for one third of worldwide water use
Breakdown of global withdrawals



Source: World Bank.

Pollution and climate change pose additional challenges

In many developing countries, pollution poses an additional constraint on supply…

The water challenges faced by many developing nations are compounded by the poor management of resources. Pollution is a major concern in many emerging countries due to the lack of adequate wastewater treatment facilities. According to the UN, roughly 90% of all wastewater in developing countries is discharged untreated, directly into the sea or rivers. Rapid urbanization in developing economies has also contributed to pollution, as the growth in the urban population has outpaced the development of sanitation facilities. UN statistics indicate that close to 800 million city dwellers—over 20% of global urban population—lack access to sanitation facilities (i.e., facilities that ensure hygienic separation of human waste from human contact).

…as many water resources have become heavily contaminated and unsuitable for human consumption.

Heavy contamination can pose serious constraints on supply. In China, for instance, results from a recent survey by the country's Ministry of Land and Resources indicate only 22% of the groundwater in the northern provinces was suitable for human contact.[8] **More than half of the groundwater supply was found to be unsuitable for either industrial use or human consumption.**

Climate change and extreme weather events make water management even more challenging.

This scenario is further complicated by extreme weather events and climate change. Extreme weather events, such as floods and droughts (including the recent severe droughts in the United States), add to the unpredictability of water availability and make water management even more challenging. Scientists believe climate change will increase the frequency of extreme weather events and exacerbate the uneven distribution of the global water supply. Arid regions will likely be the most impacted as water resources become increasingly scarce.

Competition for water on the rise

Water demand, particularly in emerging economies, is expected to continue on an upward trajectory. The growing global population (projected to total roughly 9 billion by 2050) means that the need for food, energy, and consequently water, will only increase. Inadequate water resources to meet these needs could be an impediment to growth, particularly in developing nations. We address water use in energy and agriculture in the following section.

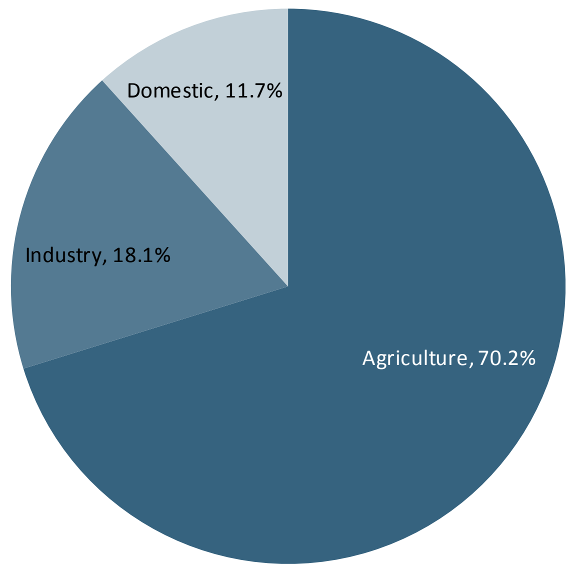
[8] China Water Risk, "North China Plain ground water: >70% unfit for human touch," February 2013.

Competing for water

Agriculture is currently the largest user of water, but it faces rising competition for resources from the industrial sector.

Agriculture is currently the largest user of water, accounting for about 70% of global water withdrawals. However, this share is projected to decline from 70% to 65%,[9] as the proportion of withdrawals from industrial activity is expected to grow. This rising demand in industrial water use is driven by growing energy needs in emerging economies like China.

Exhibit 6: Agriculture accounts for 70% of the world's water use
Breakdown of global freshwater withdrawals, 2009 data



Source: World Bank.

Water plays a critical role in the energy sector.

The water-energy nexus: energy is a growing share of water use

The growth of the urban, middle class in developing countries is expected to drive demand for energy. The average electricity generation per capita is projected to almost double from 2.9 MWh per person to 5.7 MWh per person by 2050.[10] Water plays an integral role in the energy sector, as it is required throughout the process, from extraction to refining and production to electricity generation. On the flip side, energy is also required for the treatment and transport of water, for instance, for pumping groundwater reserves or for desalination plants. The fuel mix used to meet the growing energy demand will have a direct impact on the water sector.

[9] 2030 Water Resources Group.

[10] World Energy Council, "Water for Energy," 2010.

For primary fuel production, water consumption varies vastly by source.

Among fossil fuels, the production of crude oil tends to require the largest amounts of water.

- **Crude oil:** Oil accounts for roughly a third of global fuel consumption. It also requires among the highest levels of water in its production process (on average 1.058m^3 per GJ of energy).[11] Unconventional oils (such as heavy oils and oil sands) are becoming larger parts of the energy mix, especially in North America, and they consume an estimated 2.5 to 4 times more water than conventional oil sources. These large water requirements can pose challenges for many of the world's major oil producers as these countries have an abundance of oil reserves but limited supplies of water.

Coal production is less water-intensive than oil, but the process often produces vast amounts of waste fluids that must be stored.

- **Coal:** Coal is another major fuel source, accounting for 30% of global energy use. The production of coal is less water-intensive than crude oil, averaging 0.164m^3 per GJ[12] (roughly 15% of the requirement for conventional oil). However, because water is mainly used in the process of removing impurities from coal, large volumes of waste fluid are produced. This waste product cannot be reused and must be stored, posing environmental risks if the impoundments fail (i.e., potential contamination of groundwater supplies). Although this report does not directly cover the broader environmental impact of coal, it should be noted that coal is generally considered to be a "dirty" energy source both in terms of carbon footprint and particulate emissions.

  In China, where there are vast coal reserves, about 70% of the country's energy needs are met by coal.[13] As a result, the coal industry represents a significant portion of the country's water use, accounting for 15% of total withdrawals in 2010.

The extraction of shale gas is estimated to require many times the amount of water needed for conventional gas.

- **Natural gas:** Natural gas makes up a quarter of worldwide fuel consumption but this percentage, led by the "shale revolution" in the United States, is expected to increase dramatically in the future. While the extraction of conventional natural gas involves the lowest water consumption among fossil fuels (roughly 0.109m^3 per GJ),[14] shale gas extraction is estimated to require many times the water needed in conventional gas development. Conventional (vertical) drilling requires on average between 20,000 to 80,000 gallons of water per well while unconventional (horizontal) drilling can use between 2 to 9 million gallons of water per well.[15]

  In relatively water-rich countries like Canada and the United States, the abundance of domestic water resources has helped facilitate the development of unconventional gas. In contrast, inadequate water supplies could be a constraint for prospective shale-producing countries like Mexico and China. For instance, some regions in China that are believed to contain significant amounts of shale gas deposits are located in water-scarce areas. Another major concern that has arisen with the expanded use of hydraulic fracturing is the risk of contaminating water supplies that are used for other purposes.

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[11] World Energy Council, "Water for Energy," 2010.

[12] Ibid.

[13] For additional GMI analysis on China's energy use, see "Sustainable Growth in China: Spotlight on Energy," August 2012.

[14] World Energy Council, "Water for Energy," 2010.

[15] Siemens, "Will horizontal wells become conventional in oil and gas?," January 2013.

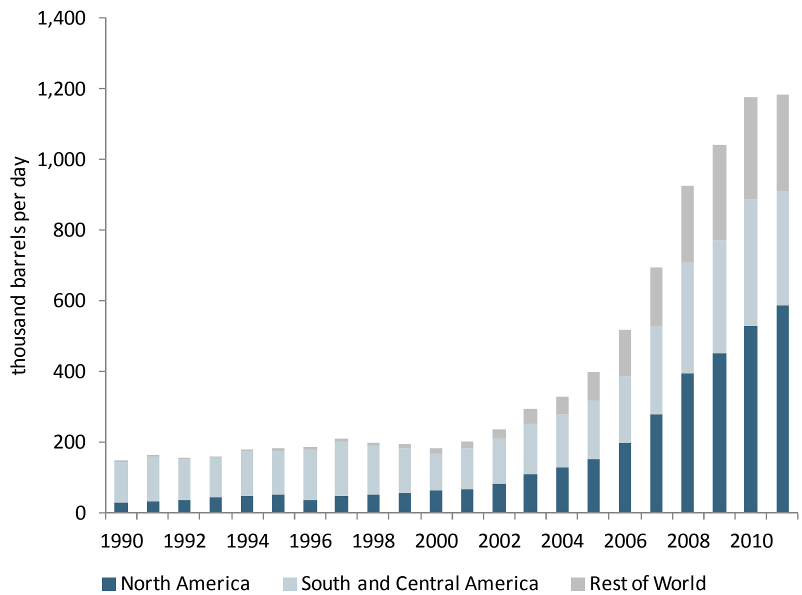
Biofuels are considered an alternative energy source to fossil fuels.

- **Biofuels:** Biofuels, produced from crops such as maize and sugarcane, is an alternative source that can help meet the growing global energy demand. Global production of biofuels has ramped up rapidly, increasing close to 200% since 2005 (see Exhibit 7). In particular, China, which has encouraged the development of the biofuels industry, increased its production levels from essentially zero in 2001 to 23 thousand barrels per day in 2011. This is still a small number compared to countries like Brazil (265 thousand barrels daily) and the United States (567 thousand barrels daily) but Chinese production levels are expected to increase.

But the use of crops as raw materials increases the competition for food and water.

However, the use of crops as raw materials increases the competition for food resources and consequently for water. The ongoing development of alternative non-food sources, such as switchgrass, *Jatropha* and algae, will be critical in order for biofuels to become a viable, sustainable energy source.

Exhibit 7: Production of biofuels has ramped up rapidly in recent years
Global biofuels production, breakdown by geography



Source: BP Statistical Review of World Energy 2012.

Power plants mainly use water for cooling.

A sizable amount of the cooling water can usually be reused.

Cooling water for electricity generation

Water also plays an important role in electricity generation, where it is used mainly in the cooling process for thermoelectric plants.[16] When water is withdrawn for cooling electric plants, a sizable amount can typically be reused. The gap between the amount of water *withdrawn* (i.e., the amount removed from the water source) and the amount of water *consumed* (i.e., the amount expended and not available for reuse) varies depending on the fuel type and on the cooling technology employed. These two factors are key determinants in how much water is available for reuse.

[16] Thermoelectric plants (which use traditional fossil fuels like coal, natural gas and oil) generate electricity by boiling water to create the steam that drives turbines. After the steam passes through the turbines, it is cooled, allowing it to condense and be reused. The bulk of the water use by power plants takes place during this cooling process and a sizable amount can typically be reused.

The amount of water available for reuse depends on the fuel source and the cooling technology employed.

There are three main cooling technologies (see Exhibit 8 for additional detail):

- **Once-through cooling:** a large amount of cooling water (usually from a nearby body of water) is withdrawn and used once before most of it is discharged back to the source, albeit at a higher temperature. Thus, while an enormous amount of water is withdrawn, the volume of water consumed tends to be quite low.
- **Recirculating cooling:** these systems use the same water repeatedly during the cooling process. Compared to once-through cooling systems, recirculating cooling technologies take in less water but they tend to *consume* much more because a large percentage of water evaporates during the process.
- **Dry cooling:** almost no water is used as the cooling is done by air. This technology is not commonly used as it is generally more expensive and more energy-intensive than the once-through and recirculating cooling systems.

Nuclear plants tend to withdraw and consume the largest amounts of water, while renewables require small amounts for cleaning.

The table in Exhibit 8 summarizes the amount of water used during electricity generation, broken down by various fuel types and the cooling technology employed. Among the most common fuel sources, nuclear plants on average withdraw and consume the most water, followed by coal-fired plants. Given the required cooling process for thermoelectric plants, it is not surprising that thermal sources require much larger amounts of water than renewable sources. Renewable fuels, such as solar photovoltaic (PV) and wind, use small amounts of water, mostly for cleaning.

Exhibit 8: Water requirements for power generation vary depending on the fuel source and cooling technology

Water withdrawn versus consumed during electricity generation

Fuel Type	Cooling technology	Water Withdrawn (gallons/MWh)	Water Consumed (gallons/MWh)
Non-renewable			
Nuclear	Once-through	25,000 - 60,000	100 - 400
	Recirculating	800 - 2,600	581 - 845
Coal	Once-through	20,000 - 50,000	100 - 317
	Recirculating	500 - 1,200	480 - 1,100
Natural Gas	Once-through	7,500 - 20,000	20 - 100
	Recirculating	150 -283	130 - 300
Renewable			
Wind	N/A	-	0 - 1
Solar photovoltaic (PV)	N/A	-	0 - 33
Concentrating Solar Power (CSP)	Recirculating	-	725 - 1,057
Biofuels	Once-through	20,000 - 50,000	300
	Recirculating	500 - 1,460	480 - 965

Note: for Wind, PV and CSP technologies, the amounts withdrawn are assumed to equal the amounts consumed.

Source: National Renewable Energy Laboratory.

Among power plants fueled by the same source, there can be a wide range of water requirements depending on the cooling technology employed (Exhibit 8). For example, according to estimates by the National Renewable Energy Laboratory,[17] a nuclear power plant that uses once-through cooling withdraws 25,000-60,000 gallons of water per megawatt-hour of electricity produced but just 100-400 gal/MWh is consumed. In

[17] The National Renewable Energy Laboratory (NREL) conducts research on renewable energy and energy efficiency for the US Department of Energy.

comparison, a nuclear plant that uses a recirculating cooling system withdraws less water (800-2,600 gal/MWh) but the amount consumed is higher (581-845 gal/MWh). The water required at specific plants varies depending on many factors, including the age of the equipment, location and local conditions such as ambient water temperature.

For hydroelectric ("hydro") power, water is not consumed during the process of harnessing electricity from water turbines. Instead, the loss of water stems from the evaporation from reservoirs. While there are limited global data on the evaporation rates at hydro plants, the median rate in the United States is estimated to be roughly 5.4 m^3 per MWh,[18] which roughly translates to 1,427 gallons per MWh. This number varies greatly depending on the specific reservoir.

The use of carbon capture and storage can potentially mitigate fossil fuel emissions but it also requires additional energy and water.

An additional factor that could affect water use in power generation is the potential use of carbon capture and storage (CCS) technology. In recent years, CCS technology has been developed to help mitigate the emissions resulting from fossil fuel combustion. However, while the use of CCS has the potential to reduce emissions, it would also require additional energy, which means additional water. A study conducted by the World Energy Council indicates that if all existing and newly-built power plants over the next 25 years are outfitted with CCS technology, the overall freshwater consumption in thermal electricity generation would be two times the levels required without CCS facilities.

Case study: Singapore, recycling waste water for industrial use

The use of treated wastewater for industrial activity is becoming more common, particularly as water-scarce regions strive to conserve resources. Singapore, which is located on a small island without natural freshwater sources, is one prime example. While it has historically relied on imports from neighboring Malaysia to meet its freshwater needs, in recent years, Singapore has invested heavily in wastewater treatment plants which use advanced membrane technologies and ultra-violet disinfection to produce "high-grade reclaimed water" (called NEWater).[19] This recycled water accounts for roughly 30% of the city-state's consumption and is mainly used by the industrial sector.

[18] World Energy Council.

[19] Public Utilities Board (PUB), Singapore's national water agency.

Agriculture remains a significant user of water

Despite the expected growth in industrial water demand, the agricultural sector will remain a significant user of water (currently 70% of global withdrawals). Estimates by the UN Food and Agriculture Organization (FAO) indicate food output must increase 70% by 2050 to feed the growing world population.

Food production accounts for a large percentage of water withdrawals in many lower-income nations.

Agricultural water use is extremely consumptive.

In many developing and lower-income nations where food production accounts for a large share of GDP, agricultural water use makes up a major percentage of withdrawals. For example, in 2009, agriculture accounted for 94% of total water withdrawals in both Cambodia and Ethiopia, and reached 90% of withdrawals in India (which has to feed 20% of the global population). This has significant implications for water supplies in these countries as agriculture-related use is much more consumptive than that of other sectors. A large percentage of the water withdrawn for agriculture is consumed (absorbed by plants, through evaporation, in transmission, etc.) and cannot be reused. (See Appendix C for discussion on water withdrawals versus consumption.)

Moreover, food production tends to be quite inefficient in many developing countries. For instance, many farmers in India utilize flood irrigation systems, which are inexpensive to employ, but typically lose half of the water to evaporation and runoff.[20] The use of more water-efficient irrigation techniques, such as drip irrigation, could increase agricultural productivity and alleviate strains on water resources. (See Case study on Israel.)

Case study: Israel, developing and exporting agricultural technologies

The arid climate and scarcity of natural water resources make water shortage a constant challenge in Israel. With freshwater resources of just 100m^3 per person (about 1% of per capita availability in the United States), the development of water technologies has been a national priority, resulting in innovations in areas such as desalination and agricultural techniques.

In agriculture, the concept of drip irrigation was commercialized by Israeli water engineers, who developed tubing that released water in slow and balanced drips, reducing loss through evaporation and thus allowing farmers to minimize the water needed for crops. The efficiency of Israel's agricultural sector allowed the country to export $2.13 billion worth of fresh and processed agricultural goods in 2010 (about 3% of total exports),[21] mainly to European countries. In addition, the country is a global leader in treating and recycling wastewater for agricultural use. Currently over 80% of household wastewater is treated and reused for irrigation, about four times the next highest rate in the world (approximately 20% in Spain).[22] Israel has set a goal of recycling 95% of the country's wastewater by 2020.

These water innovations are also becoming important exports for Israel. National statistics indicate that exports relating to water technology grew almost threefold in recent years, from $700 million in 2006 to roughly $2 billion in 2011 (3% of total exports). With rising global demand for high-quality potable water, this figure is projected to reach $2.7 billion by 2014. Some major export destinations currently include the United States, Germany, Italy, Spain and Australia. One potential market for growth for these technologies could be China. Israel signed a financial protocol in March 2012 for a special line of credit of NIS 1 billion (approximately US$300 million) to finance the exports of water technologies for agricultural use in China.

[20] Worldwatch Institute.

[21] Israel Ministry of Agriculture and Rural Development.

[22] Invest in Israel, Ministry of Industry, Trade and Labor.

Major exporters of agricultural goods are also major water users.

Nations that are major exporters of agricultural goods also tend to be major water users. In particular, the United States accounts for 12% of all global withdrawals, due in large part to the country's exports: the United States is the world's largest exporter of agricultural goods, which include maize, soybeans and wheat. Hence, it is also the world's largest exporter of virtual water.

The role of virtual water trade

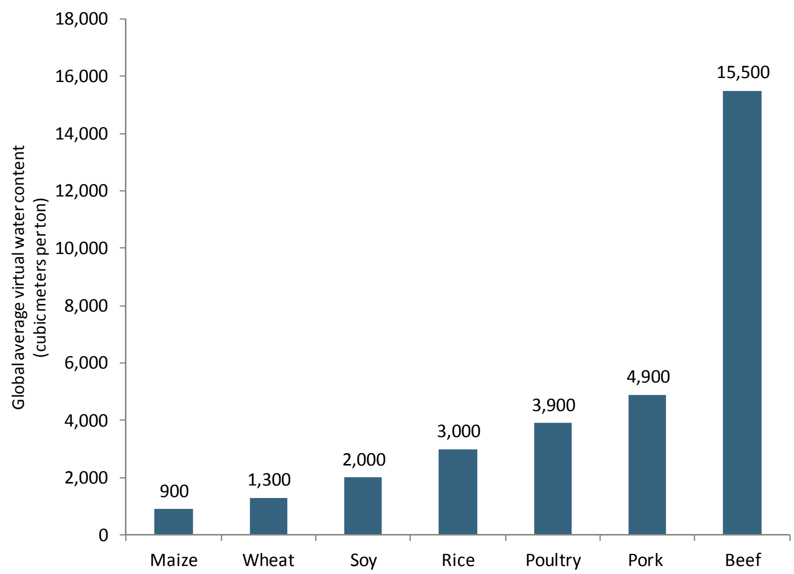
The imports and exports of agricultural products are a form of "virtual water" trade.

Through the export of agricultural goods, the United States is also exporting large amounts of "virtual water." Virtual water refers to "the water used (or consumed) in the development or production of a good or commodity, typically agricultural products".[23] As the production and distribution of any agricultural good requires the consumption of water, the trade of products can be viewed as the trade or flow of one region's water resources to another. For example, when a country imports a ton of wheat, it is importing virtual water, i.e., the water needed to produce the crop.

Meat products have very high virtual water contents.

The amount of water embedded in different agricultural products varies greatly (see Exhibit 9). Meat products require much more water than grains. For example, the virtual water content of beef is roughly 17 times the amount in maize and 12 times the content in wheat.

Exhibit 9: Meat production, in particular beef, requires extremely large amounts of water
Global average virtual water content of key agricultural products, per ton of food



Source: United States National Intelligence Council, UNESCO-IHE Institute for Water Education.

Virtual water trade could alleviate the uneven distribution of water…

Because water is not a commodity that can be easily or directly traded on the open market, virtual water trade has been suggested as a way to alleviate the uneven distribution of water by allowing for the transfer of water resources from water-rich nations to water-scarce regions. International trade movements have shown signs of this trend. One recent study[24] estimates that between 1986 and 2007, the volume of water associated with global food trade doubled to equal roughly 20% of global freshwater withdrawals for agriculture.

[23] United States National Intelligence Council, "Global Water Security report," February 2012.

[24] Proceedings of the National Academy of Sciences of the United States of America (PNAS), "Evolution of the global virtual water trade network," April 2012.

While South America as a region has become a major virtual water exporter (particularly to Asia), the United States remains the top exporter. On the demand side, Asia has become a significant virtual water importer, with China as the largest importer. This is driven by soy-based commodities for animal feed to satisfy the nation's growing meat consumption.

…and help developing countries meet changing dietary demands…

The role of virtual water trade is likely to grow in importance as developing countries manage their populations' changing dietary preferences. Economic growth and the expansion of the middle class, especially in emerging countries like the BRICs, have led to a shift in diet from predominantly plant-based foods to more water-intensive products, such as meat and dairy.

For example, as China's middle class[25] grew from less than 1% of the total population in 1990 to 40% of the population today, per capita pork consumption increased almost 100% to reach 38.4 kilograms per person in 2012—1.5 times the per capita level in the United States. See Exhibit 10. China now accounts for about half of global pork consumption.

The continued expansion of the middle class in emerging economies spells additional demand for meat products and potential opportunities for virtual water trade.

Exhibit 10: China is the world's largest consumer of pork
Per capita meat consumption in the US and China

Meat consumption per person (kilograms per capita)

	US			China		
	1990	2012	% change	1990	2012	% change
Chicken	30.6	42.0	37%	2.1	10.0	375%
Beef	43.6	36.0	-18%	1.0	4.1	324%
Pork	28.7	26.9	-6%	19.7	38.4	95%
Total	**102.9**	**104.8**	**2%**	**22.8**	**52.5**	**130%**

Source: US Department of Agriculture.

…it could also allow for greater efficiency of water use.

Some studies have also indicated that virtual water trade could allow for greater efficiency of water use. For instance, China's imports of soy-based products come from three major countries, Brazil, the United States and Argentina, which are able to produce soy with less water than domestic production in China. Another example is Saudi Arabia, which is attempting to alleviate strains on water resources by replacing domestic wheat production with imports (See Case study on Saudi Arabia). These flows of virtual water, from relatively more-efficient countries to less-efficient ones, provide opportunities to reduce water consumption. One estimate[26] indicates global water savings equaled roughly 9% of agricultural water use in 2007.

[25] The middle class is defined as those with annual income between $6,000 and $30,000, PPP-adjusted.

[26] Proceedings of the National Academy of Sciences of the United States of America (PNAS), "Evolution of the global virtual water trade network," April 2012.

Case study: Saudi Arabia, replacing inefficient domestic wheat production with imports

Saudi Arabia faces significant water challenges. Freshwater resources total roughly 90m^3 per capita, less than 1% of the availability per person in the United States. To reduce agricultural water use, which accounts for about 85% of the country's withdrawals, the government announced a plan in 2008 to phase out domestic wheat production by 2016. Consumption needs are expected to be met through imports instead. This decision represented a dramatic change in the country's longstanding goal to achieve self-sufficiency in wheat production. Since 2008, wheat production has declined over 30%, reaching 1.2 million metric tons in 2011 while wheat imports more than doubled over the same period, totaling 2.9 billion metric tons in 2011.[27] Major wheat suppliers to the Saudi market include Canada (30% of total wheat imports), Germany (17%) and the United States (12%).

In addition, as part of the country's strategy to ensure food security, the government has enacted incentives for private sector agricultural investment in foreign countries. The program includes an $800 million fund to provide credit facilities for Saudi investment in agricultural ventures abroad.[28] Under the initiative, Saudi firms have invested in many countries in Africa, given the region's geographical proximity and the availability of underutilized land in countries such as Ethiopia.[29]

[27] US Department of Agriculture.

[28] Ministry of Agriculture, Kingdom of Saudi Arabia.

[29] Other countries have also begun "outsourcing" their food production to meet domestic demand. For example, India grows crops in Ethiopia, Kenya, Madagascar and other nations.

Market opportunities in water risk mitigation

Country efforts to address water challenges tend to focus on the supply.

Initiatives to manage demand are complicated due to the heavily subsidized water costs in many countries.

Countries adopt strategies to address water risk

Many countries, particularly those in water-scarce areas, have developed strategies to mitigate water challenges. Initiatives to date have mainly focused on expanding supply, for example, through wastewater treatment or desalination (see Appendix D for discussion on desalination).

Efforts to restrain demand are complicated, as water costs are heavily subsidized in many countries, particularly for agricultural use. For example, analysis by the United States National Intelligence Council[30] indicates that water prices for the agricultural sector averages roughly $0.10 per cubic meter in most countries, compared to $0.60 to $3.00 per cubic meter for industrial and household use. In many OECD countries, the water charges paid by farmers tend to cover just the operation and maintenance costs for the water supply, not the share of capital costs for infrastructure.[31]

The low price of water charged in most regions of the world makes it challenging to incentivize users (particularly those in relatively water-rich regions) to improve efficiency. For instance, an initiative on the demand side is the WaterSense program, a partnership program by the US Environmental Protection Agency (EPA) that labels products certified to be at least 20% more water-efficient. Since the program's inception in 2006, it has helped save an estimated 287 billion gallons of water, or roughly 48 billion gallons per year. To provide perspective, the **daily** water withdrawal in the United States is approximately 410 billion gallons.

The global water industry, estimated at over $300 billion, seeks to seize on the business opportunity to provide solutions.

Opportunities for the water sector

As countries seek to address water challenges, companies in the water sector have seized on the business opportunity to provide solutions. The global water industry, which is estimated to total over $300 billion,[32] includes sectors like desalination, wastewater treatment and water-efficiency technologies. Within the industry, there are companies that focus exclusively on the water sector (such as Veolia in France and Miya in Israel) while others are part of business lines in larger conglomerates (for example, General Electric in the United States and Doosan in South Korea). The demand for these services and products is expected to continue to rise as increasing numbers of countries face mounting water issues. Developing economies also offer substantial potential for the water sector, as these markets construct new infrastructure systems.

The private sector increasingly recognizes water risk.

Companies incorporate water in sustainability efforts

The broader private sector increasingly recognizes the impact of water risk on their businesses, as companies incorporate water-related initiatives into sustainability efforts. In particular, industries in which water is a key input, such as the food and beverages sectors, have been proactive in addressing water-related risks. Most corporate programs today are focused on controlling water use and minimizing costs in direct operations. A subset moves beyond this to also address water risk in the supply chain. Finally, some companies are seizing on the opportunities presented by water challenges to offer products and services that mitigate the risk. (See Appendix E for additional details on private sector initiatives.)

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30 United States National Intelligence Council, "Global Water Security report," February 2012.

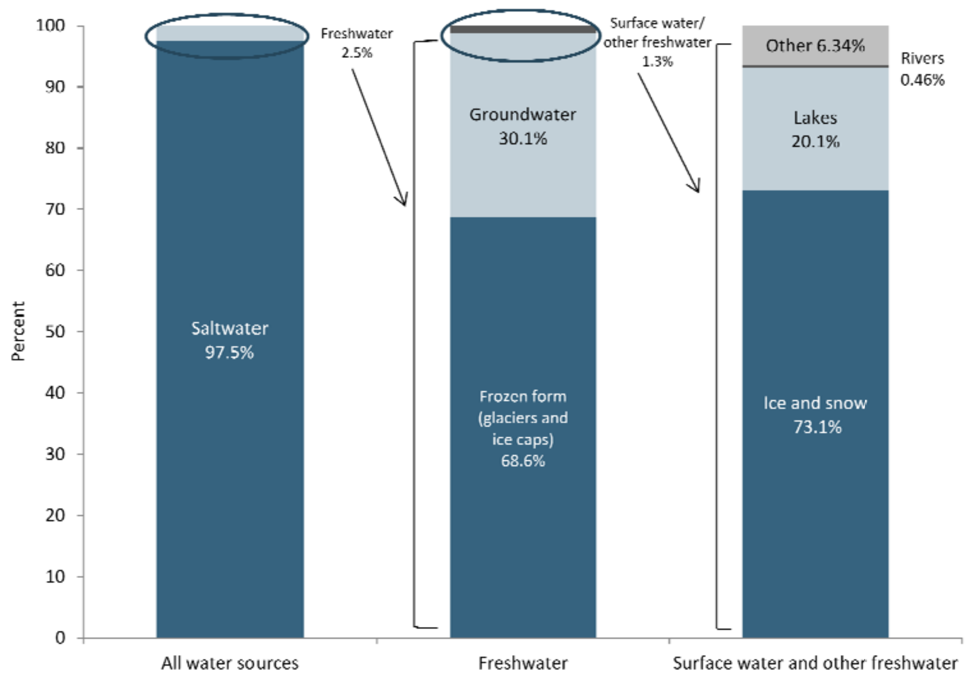
31 OECD, "Water resources in agriculture: outlook and policy issues," 2010.

32 Global Water Intelligence estimates a global market size of $316 billion.

Appendix A: The world's water supply

According to the United States Geological Survey (USGS),[33] the volume of water on Earth is estimated to total roughly 1.38 billion cubic kilometers. However, only a small portion is suitable and available for human consumption. In fact, roughly 97.5% of the world's water is saltwater, found mainly in oceans, which is unsuitable for use without processing.

Exhibit 11: Freshwater resources make up just 2.5% of the global water supply
Breakdown of the world's water resources



Source: United States Geological Survey.

The remaining 2.5% is freshwater resources, of which 68.6% is frozen in the form of glaciers and ice caps and roughly 30.1% is groundwater.[34] The residual 1.3% is surface water[35] and other sources of potentially available freshwater. Rivers and lakes, which are major sources for much of current human consumption, make up just 0.3% of global freshwater. See Exhibit 11 above. This small slice of the global supply fulfills a large portion of our daily water needs.

[33] The United States Geological Survey (USGS) is the federal science agency responsible for water, earth, biological science and civilian mapping.

[34] Groundwater is water stored in aquifers under the Earth's surface.

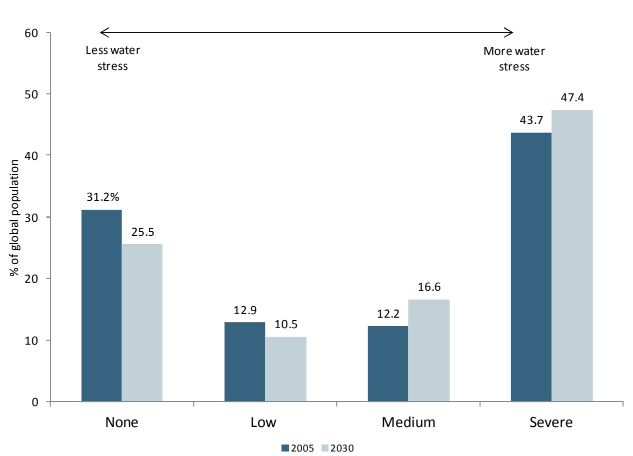
[35] Surface water is defined as water found on the Earth's surface, such as in rivers, lakes, streams or reservoirs.

Appendix B: Water stress is a rising concern in developing nations

The OECD estimates there are approximately 2.8 billion people living in areas under severe water stress.[36] The bulk of the affected population is located in non-OECD economies. In fact, close to two-thirds reside in the BRIC (Brazil, Russia, India and China) countries.

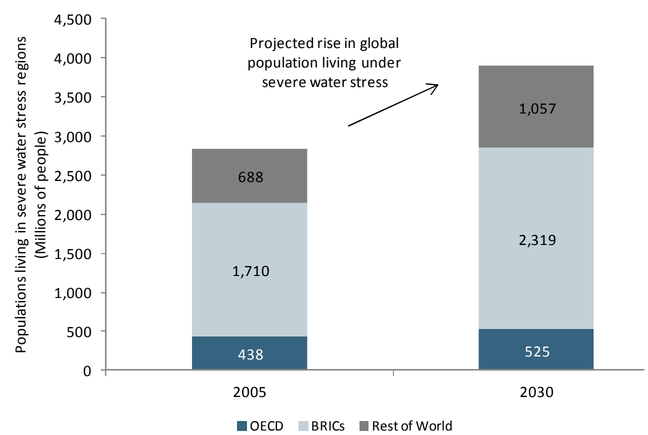
Moreover, the global number of those living under severe water stress is projected to increase by an additional one billion people by 2030 to total 3.9 billion. This is equivalent to nearly half of the projected global population. See Exhibit 12. The majority of this increase is projected to include people living in the BRICs as well as in regions like Southern Asia and Africa. As Exhibit 13 illustrates, **roughly 60% of the incremental population experiencing severe water stress is expected to reside in the BRICs.** The growing water demand in developing economies is a major contributor to increasing water stress in these regions.

Exhibit 12: Close to half of the global population could be living in regions with severe water stress by 2030
Populations living under various levels of water stress, 2005 versus 2030 projections



Source: OECD.

Exhibit 13: 60% of the additional people in high water stress areas are projected to reside in the BRICs
Breakdown of populations living under severe water stress by geography, 2005 vs. 2030 projections



Source: OECD.

[36] The definition used by the OECD for water stress refers to water withdrawals as a percentage of total renewable resource. Below 10% is considered no stress, 10-20% is low stress, 20-40% is medium stress and above 40% is severe stress.

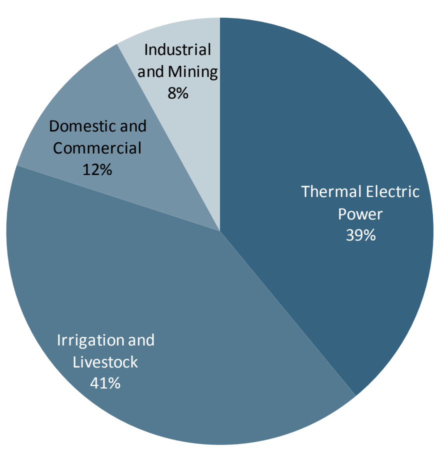
Appendix C: Water withdrawal versus consumption

While the water withdrawal numbers are useful, another key metric to consider is water consumption. Consumptive use refers to water that is removed and not returned to its source. Exhibits 14 and 15 highlight the difference between volumes withdrawn versus volumes consumed per sector in the United States. Agriculture-related use is much more consumptive than that of other sectors—a large percentage of the water is expended (absorbed by plants, through evaporation, in transmission, etc.) and cannot be reused. In the United States, agriculture accounted for 41% of withdrawal but made up 85% of consumption volumes.

In contrast, water withdrawn by the industrial sector has a lower rate of consumption. A large amount of the water for cooling thermal electric plants can be used again, though the quality may vary. While thermoelectric power uses accounted for almost 40% of water withdrawal in the United States, it only made up 3% of consumption. The USGS estimates that when water is withdrawn for US industrial or domestic use, about 90% can be reused; this percentage is about 50% for irrigation. International data focus on withdrawal, making it hard to find comparable consumption numbers for other countries but the overall pattern is likely the same.

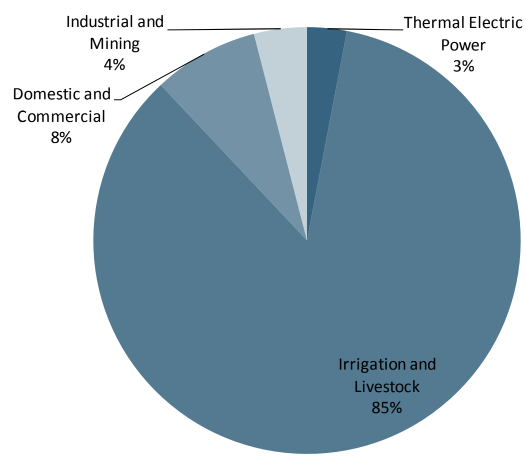
In many developing countries, pollution is a serious constraint on water availability and reuse. In some nations, heavy contamination has made water resources unsuitable for human consumption or for industrial use.

Exhibit 14: While power generation accounts for 40% of withdrawals...
Breakdown of water withdrawal in the US



Source: World Economic Forum.

Exhibit 15: ...only 3% is consumed
Breakdown of water consumption in the US



Source: World Economic Forum.

Appendix D: Building freshwater supply through desalination

Arid countries lead the way on desalination capacity.

Desalination is the process of removing salts and other minerals from sea or saline water to produce a potable supply of water. Currently, there are approximately 15,000 desalination plants worldwide, the majority of which are located in water-scarce regions like the Middle East. It is estimated that Saudi Arabia has about 25% of the global desalination capacity, which provides roughly 70% of the country's water used in cities and by the industrial sector. Amid concerns about the growing water demand and potential shortages, other countries like Australia, China and the United States, have also started to expand their desalination capacity.

Desalination process is expensive and energy-intensive, but costs have been declining.

The desalination process is expensive, primarily due to the large amounts of energy required in the procedure. While the unit cost varies depending on many factors (such as salinity levels of the water source, type of technology, proximity to energy source, etc.), the general trend has been a decline in costs with the development of more efficient and less expensive technologies. This has been driven largely by a shift from the use of traditional thermal technology to the less energy-intensive reverse osmosis process. Anecdotal data indicate the cost for reverse osmosis desalination plants has fallen from $1.50/cubic meter of water in the 1990s to below $0.60/cubic meter in recent facilities. In order to bring down costs, many newer plants minimize energy use by building on-site power plants to provide electricity directly to the facility and by installing energy-recovery systems to reuse energy during the process.

Greater reliance on desalination to meet global water needs has raised concerns regarding the associated environmental impact, including the greenhouse gas emissions from fossil fuels that power the facilities as well as the brine and other chemicals produced from the process. One area under development is the use of renewable sources, such as solar energy, to power the desalination plants.

Appendix E: Private sector recognizes water risk

Looking at anecdotal examples of water-related corporate actions, there are three broad categories of initiatives. The first group, which includes most corporate actions today, is focused on direct operations, "the low-hanging fruit," where companies target water in their day-to-day businesses. The second type comprises a smaller set of companies that have moved beyond the direct business impact to also recognize the importance of addressing water risk in their supply chains. In the last category, some companies are seizing on the opportunities presented by water challenges to offer products and services that mitigate the risk.

Below we provide some examples from large companies in various industries.

Focusing on water use in business operations:

- **Starbucks** (Consumer Discretionary) has set a target to reduce water consumption in its stores by 25% by 2015. One effort includes the replacement of "dipper wells" in stores with manual faucets, which use 15% less water. The company has also begun to install filtration systems that reduce wastewater by 50%.
- **Intel** (Information Technology) is working to reduce its water footprint by minimizing the amount of ultra-pure water (UPW) needed to clean silicon wafers during the fabrication process. The volume of water required to make 1 gallon of UPW has been reduced from 2 gallons to between 1.25 to 1.5 gallons. The water, after being used to clean wafers, is reused in other equipment. In 2011, 30% of the company's water withdrawals were recycled.
- **General Motors** (Automobiles) has committed to reducing water consumption in its manufacturing facilities. By implementing water conservation strategies at every plant, water use was reduced by 32% on a per-vehicle-produced basis between 2005 and 2010. One example is a new assembly plant in Mexico, which was designed with a zero discharge concept (90% of wastewater is treated and reused in the manufacturing process). This design is estimated to reduce the amount of water used by 20 million gallons annually.
- **Southern Company** (Utilities) withdraws over 6 billion gallons of water each day for use in the electricity generation process but approximately 95% is returned to the source (rivers, lakes etc.). The company has plans to establish a water research facility that will develop technologies to improve water efficiency and quality.
- **Cenovus** (Energy) aims to improve the amount of recycled water used in its oil sands operations. In 2011, the oil sands recycle rate was 77%. In addition, the company encourages the use of alternative water sources, such as brackish water (which has more salinity than freshwater), versus withdrawing freshwater. Over 70% of the water used for production in 2011 was saline.

Addressing water-related risk in the supply chain:

- **Pfizer** (Healthcare) aims to reduce the water used in its facilities by 2% each year, by increasing the treatment of wastewater and the reuse of treated water in cooling towers. The company has also initiated a program to work with suppliers to monitor water use and improve conservation efforts.
- **Coca-Cola** (Beverages) has committed to improving water efficiency by 20% from 2004 levels (achieved in 2011) and to treating all wastewater used during the manufacturing process (in progress). The company has also pledged by 2020, to replenish water equal to the amount used in the production process back to nature. In 2011, an estimated 35% of the water used was replenished through community projects in locations such as India, China, Colombia and Nicaragua.

- **ConAgra** (Food) reduced total water use by 4.8% and water intensity (water use per pound of production) by 2.7%, compared to 2008 levels. The company has also started to assess water-related risks at its major suppliers around the world and is working to integrate this information into its long-term sourcing strategy.

Creating revenue opportunities:

- **General Electric** (GE) (Industrials) reduced its freshwater consumption by 35% in 2011, from 2006 levels. In addition to addressing water in its operations, the company is also working to develop products that minimize water consumption, such as the GE "ecomagination" brand that offers operationally and environmentally efficient products.
- **Syngenta International** (Fertilizers and Agricultural Chemicals) helps farmers conserve water by developing products, such as improved seeds and crop protection products, that use natural resources more efficiently and improve farm productivity. One product is estimated to reduce the amount of water required for wheat crops by 10%.
- **DuPont** (Chemicals) aims to reduce water consumption at sites located in water-scarce or water-stressed regions by at least 30%. In 2011, absolute water consumption in these areas declined by 9.2%, compared to 2004 levels. The company also develops technologies in industrial wastewater treatment, particularly for the oil and gas industry.

Public disclosures on water risks are improving, but remain inconsistent

Public companies are gradually improving their disclosures on water-related risks, due in part to SEC formal guidance issued in 2010 on climate change-related disclosures made in financial filings. Recent analysis by Ceres (a non-profit organization focused on sustainability issues in the private sector) on water-related filings indicated that while disclosure of water risks has increased since 2009, the level of detail and clarity varies greatly. Quantitative data also remain scarce.

Industries that rely on water as a critical input, such as the Food and Beverages sectors, tend to provide more detailed discussions about the impact of water risks on their businesses. Similarly, given the important role of water in electricity generation, companies in the Utilities sector have improved their water-related disclosures. The filings also address the water-related regulations faced by utilities in the United States, such as those imposed by the Environmental Protection Agency on cooling structures and water discharges.

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