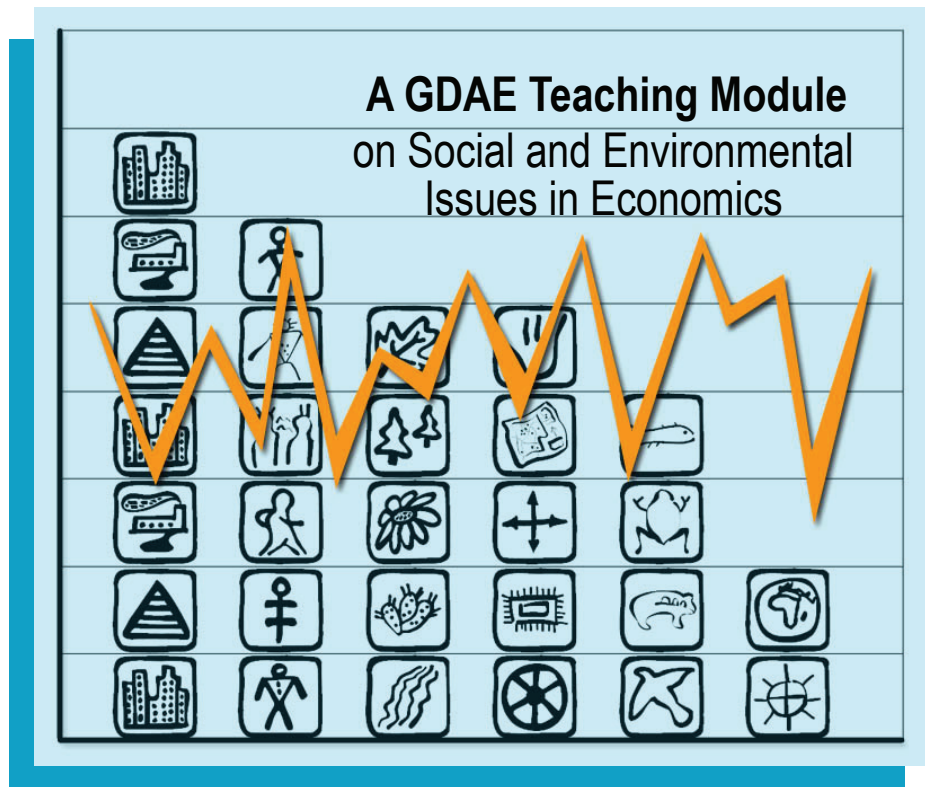


# Water: Economics and Policy

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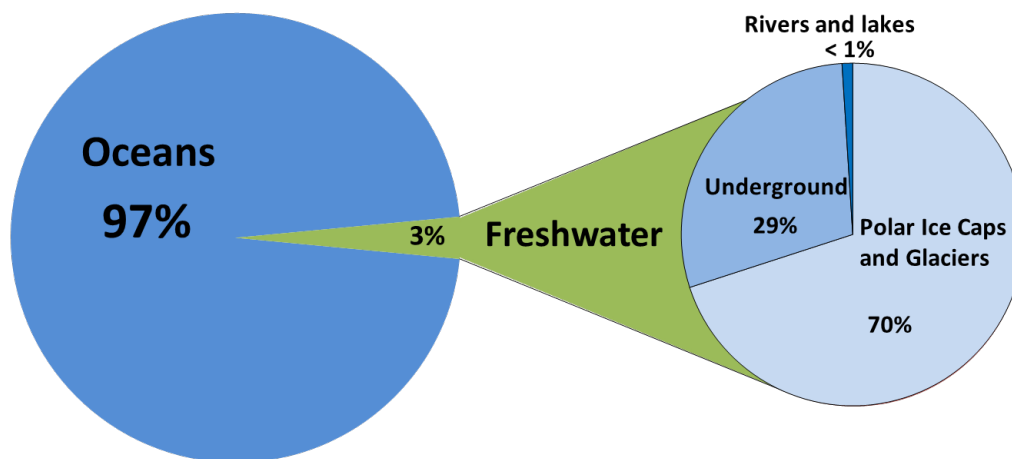
# Water: Economics and Policy

Water is the driving force of all nature.  
-- Leonardo da Vinci

## 1. GLOBAL SUPPLY AND DEMAND FOR WATER

Water is a unique natural resource that forms the basis for life on Earth. Two thirds of the planet's surface is covered by oceans. 97% of the Earth's water is salt water and only 3% is freshwater – 70% of which is in solid form, captured by the polar ice caps and by glaciers (Fig. 1). Of the 30% of freshwater that is available in its liquid form, most is in underground aquifers. The freshwater that makes up all of the terrestrial sources such as rivers and lakes only represents 1% of the planet's freshwater.

Figure 1: The composition of the planet's water



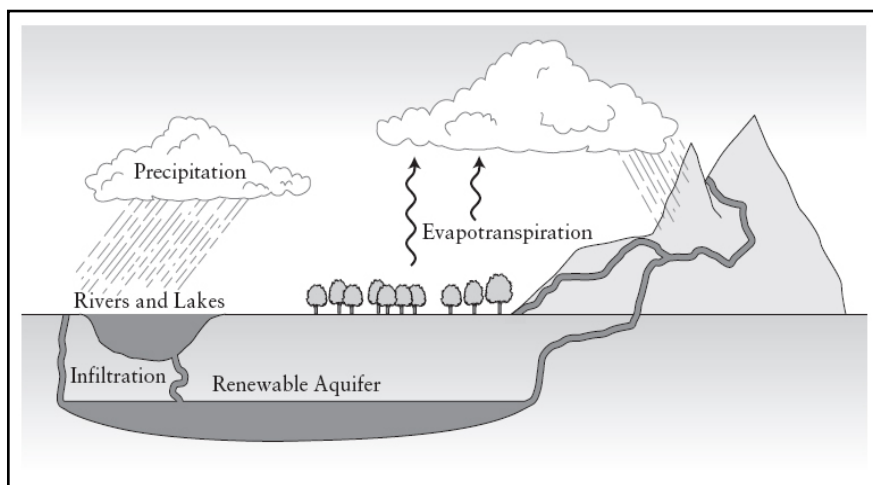
Source: Getting the picture: our changing climate - <http://gettingthepicture.info/3/>;  
[http://www.unwater.org/downloads/Water\\_facts\\_and\\_trends.pdf](http://www.unwater.org/downloads/Water_facts_and_trends.pdf)

Water can be characterized as a renewable resource, since it can generally be reused indefinitely as long as it is not severely polluted. Also, water is continually purified in a process known as the **hydrologic cycle** (Fig. 2). Water evaporates from lakes, rivers, oceans, and through the evapotranspiration of living organisms, returning as precipitation that replenishes the freshwater sources, whether on the ground or underground.

The flows of freshwater that are recycled in the hydrologic cycle are at times stocked in two types of natural reservoirs, bodies of surface water such as lakes and rivers, and stocks of groundwater, which are found in underground aquifers. While aquifers are

replenished as a result of infiltration, most aquifers have very long replenishment times, making them essentially nonrenewable resources on a human time scale. Aquifers under the Sahara, for example, are thousands of years old, and are sometimes referred to as “fossil water.” Thus the analysis of water systems combines elements of renewable and non-renewable resource theory.

**Figure 2: The Hydrologic Cycle**



Evaporation fueled by the sun’s energy lifts 500,000 cubic kilometers of moisture into the atmosphere each year—86 % from the oceans and 14 % from the land. An equal amount falls back to earth as rain, sleet, or snow, but it is distributed in different proportions: whereas the continents lose about 70,000 cubic kilometers through evaporation, they gain 110,000 through precipitation. As a result, roughly 40,000 cubic kilometers are transferred from the sea to the land each year.

The total available supply of 40,000 cubic kilometers converts to about 5,700 cubic meters per person per year. Hydrologists have established that, considering the water needs of modern societies, a threshold of 2,000 cubic meters per person per year represents the level above which a population can be sustained comfortably.<sup>1</sup> But while the total global water supply is sufficient to meet human needs, not all water can be captured for human use. As much as two-thirds of the total water supply runs off as floods. Some water must also be allocated to meet ecological demands, such as supplying wetlands and wildlife habitat.

According to the United Nations, an area is said to be experiencing **water stress** when annual water supplies fall below 1,700 cubic meters per person per year.<sup>2</sup> A region is said to face **water scarcity** when supplies fall below 1,000 cubic meters per person, and **absolute water scarcity** when supplies drop below 500 cubic meters per person per year.<sup>3</sup>

<sup>1</sup> Postel, 1992. Hydrology is the scientific study of the distribution and movement of water on the earth’s surface, underground, and in the atmosphere.

<sup>2</sup> Center for Strategic and International Studies, 2005.

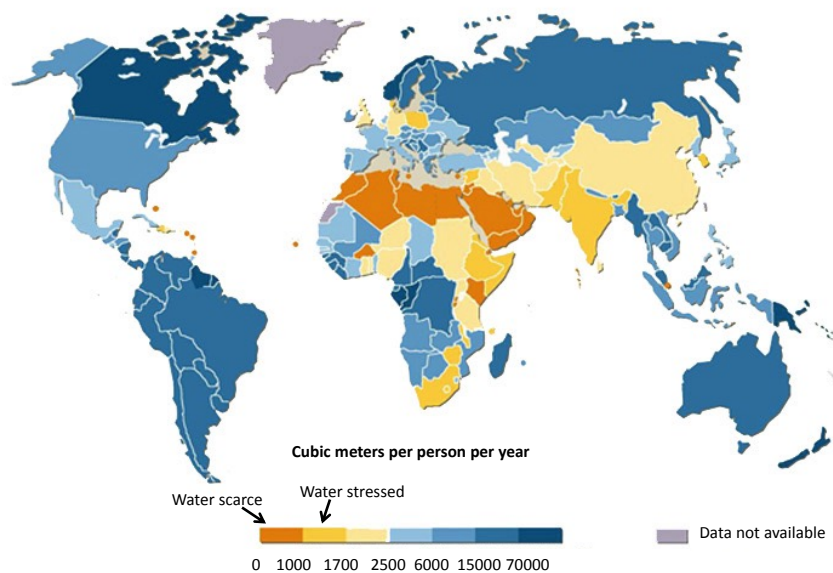
<sup>3</sup> U.N. Food and Agriculture Organization (FAO), 2012.

Global water supplies are not evenly distributed geographically or seasonally. Some regions of the world have abundant water resources, while others suffer from a scarcity of water. The symptoms of physical water scarcity include severe environmental degradation, declining groundwater, and unequal water distribution, and they cause severe constraints on food production, economic development, and protection of natural systems.

In addition to physical scarcity, the concept of **economic water scarcity** relates to situations where a lack of proper infrastructure in water distribution, water recycling and treatment, and sanitation, leads to inadequate water supply. This situation often causes the population to rely on unhealthy sources of water, with tragic health and mortality consequences, as is the case in large parts of Africa, where waterborne diseases are the leading cause of children mortality. Worldwide, 6000 children die each day as a result of diseases caused by ingestion of unsafe water.<sup>4</sup>

Figure 3 shows the countries that are already experiencing water stress or water scarcity in physical terms. The countries with the most limited water supplies are in North Africa and the Middle East. Water stressed countries include India, South Africa, and Poland.

**Figure 3: Global Freshwater Availability, 2007**

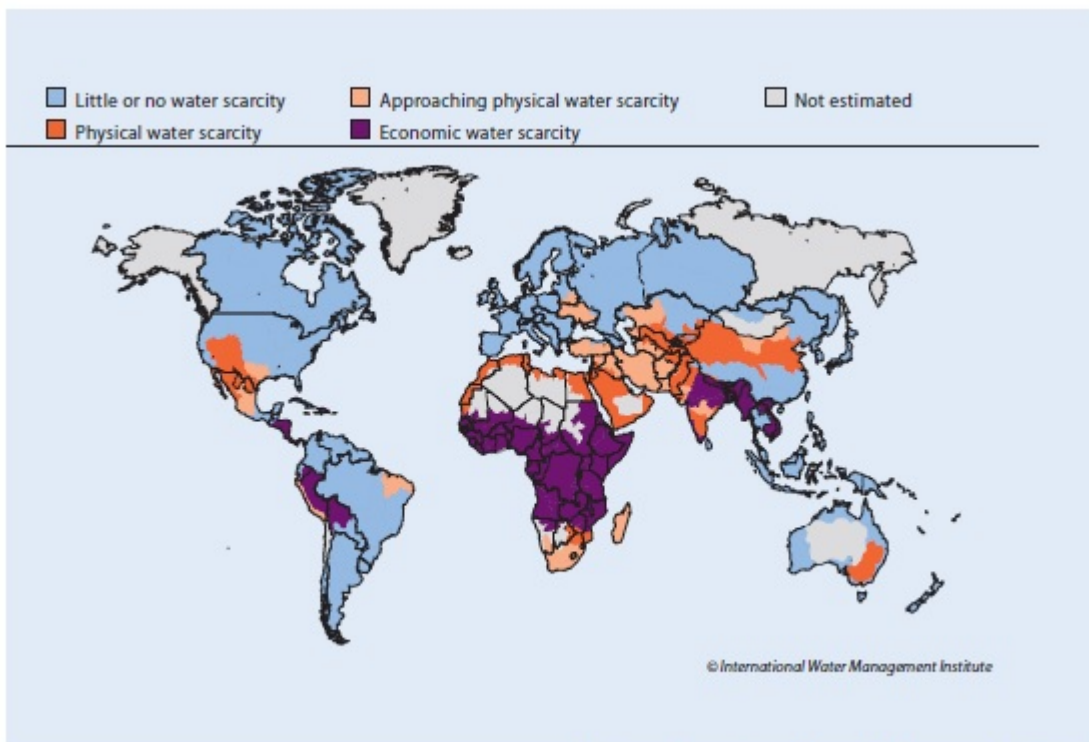


Source: UNEP, 2008.

<sup>4</sup> UNICEF, [http://www.unicef.org/media/media\\_21423.html](http://www.unicef.org/media/media_21423.html).

Figure 4 presents a more precise picture of water scarcity by displaying not only physical scarcity but also economic scarcity, showing that many African countries which are not water scarce in physical terms, are experiencing water economic scarcity and low access to clean water. Figure 4 also shows regional variability inside countries – The United States and Australia are on average well above the threshold of 2000 cubic meters of water per capita per year, but entire regions such as the US Western States and the Southeastern part of Australia are experiencing physical water scarcity.

**Figure 4: Physical Water Scarcity vs. Economic Water Scarcity**



Source: International Water Management Institute

Reproduced by Worldwatch Institute, March 2013, <http://vitalsigns.worldwatch.org/node/180>.

Some of the most populated areas of the world are experiencing increasing water stress and scarcity (see Table 1) and the problem will only intensify throughout the 21<sup>st</sup> century, under the growing pressures of population growth and climate change, which will worsen water availability in areas that are already arid and semi-arid.

The Middle East and North Africa region is the most water scarce (average 500 cubic meters per person per year) with a population of 432 million in 2007, expected to increase to 692 million in 2050.<sup>5</sup> Sub-Saharan Africa already suffers from water scarcity (1000 cubic meters per person per year) with a current population of 936 million in 2013, expected to double by 2050.<sup>6</sup>

<sup>5</sup> Population Reference Bureau, 2008 <http://www.prb.org/Publications/Articles/2008/mafertilitydecline.aspx>.

<sup>6</sup> World Bank, <http://data.worldbank.org/region/SSA>; Population Reference Bureau <http://www.prb.org/Publications/Datasheets/2013/2013-world-population-data-sheet/data-sheet.aspx>

**Table 1: Water Availability per region (2012)**

Region	Average water availability (cubic meters/person)
Middle East and North Africa	500
Sub-Saharan Africa	1,000
Caribbean	2,466
Asia/Pacific	2,970
Europe	4,741
Latin America	7,200
North America (including Mexico)	13,401

Source: FAO, Aquastat (2013), UNESCO (2012) – from [vitalsigns.worldwatch.org](http://vitalsigns.worldwatch.org)

To examine those challenges in more depth, we turn first to a more detailed analysis of the uses of water in modern human societies, and indicators that can be used to measure the impact of our water use.

## Uses of water

When considering the use of water, it is useful to think of water along three critical dimensions: **consumption**, **withdrawal**, and **quality**.

**Consumption** refers to water that disappears or is diverted from its source, for example by evaporation, incorporation into crops or industrial processes, drinking water, etc. The source may or may not eventually be replenished. If replenished, the process could potentially take many years— decades, centuries, or longer.

**Withdrawal** refers to water that is essentially “sucked up” for a given use, but then returned to its source. The quality of the returned water may or may not be the same as it was prior to removal.

**Quality** is a broad term that can refer to pollutants that enter the water; changes to oxygen content, salinity, and acidity; temperature changes; destruction of organisms that live in the water; and so on.<sup>7</sup>

Considering these three dimensions of water, scientists have proposed a decomposition of water into three categories of water that allow for a more precise analysis of human use of freshwater<sup>8</sup>:

**Green water:** the water that exists in flux in natural ecosystems, as clouds, mist, rain, as well as the humidity that is captured by the soils and plants.

<sup>7</sup> Definitions are adapted from Glassman, et al., 2011. [http://www.nationalfoodhub.com/images/THE\\_WATER-ENERGY\\_NEXUS\\_REPORT.pdf](http://www.nationalfoodhub.com/images/THE_WATER-ENERGY_NEXUS_REPORT.pdf).

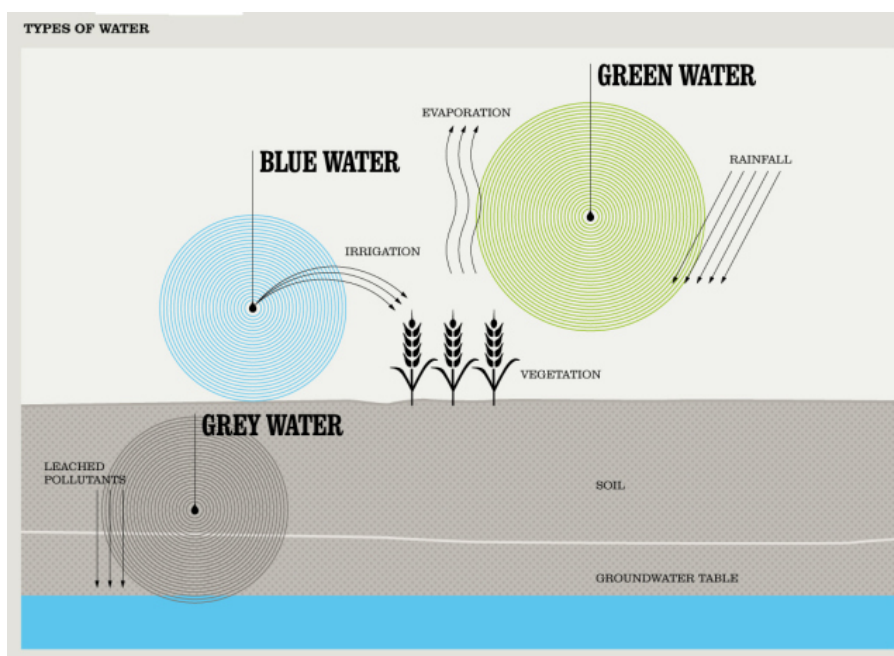
<sup>8</sup> Hoekstra and Hung, 2002.

**Blue water:** the water withdrawn from water stocks, i.e. bodies of water such as lakes, reservoirs, and groundwater aquifers – and which is used as input in all human activities (irrigated agriculture, industry, domestic use)

**Gray water:** the freshwater needed in order to dilute and flush away all the pollutants that result from all human activities. It is quantified as the volume of water that is required to assimilate pollutants to such an extent that the quality of the ambient water remains above agreed water quality standards.

Figure 5 gives a representation of the three types of water as used in agriculture.

**Figure 5: Green, Blue, and Gray Water uses of Water for Agriculture**



Source: <https://thelivinglabiesd.wordpress.com/2012/11/14/sustainable-water-the-concept-of-water-footprint/>

Agriculture uses as inputs both green water (rain-fed crops) and blue water (irrigated crops). It also requires gray water, to flush and dilute the pollutants used in industrial fertilizers (nitrates) and pesticides and herbicides.

Industry uses mostly blue water, which is withdrawn for many usages such as cooling (thermoelectric plants, nuclear plants, steel industry). Industries also use water for hydraulic pressure (enormous amounts of water are used in fracking the underground rocks imbued with gas) or as an input in fabrication processes – for instance the production of paper. Green water is also an input of industrial processes since some rain-fed agricultural goods are also used as major ingredients in industrial production. This is the case with biofuels, which come from crops (primarily corn and soy) produced to make ethanol. Additionally, large amounts of gray water are needed to dilute all the industrial chemical pollutants that result from the industrial water uses.



Domestic and municipal use of water comes strictly from blue water sources, used for sanitation, bathing and cooking, as well as recreational uses (swimming pools, watering lawns, etc.).

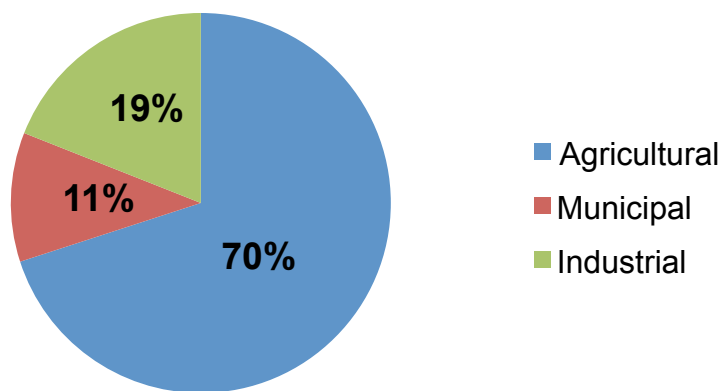
### Indicators of water use

Traditionally, the indicator used to measure the impact of human activities on water resources is the amount of total freshwater withdrawal for the various sectors of the economy. These water withdrawals from lakes, rivers, dams, reservoirs and aquifers, correspond in the above classification to “blue water”.

The largest water consuming sector of human activities is agriculture. Although 83 percent of the world’s cropland is rain-fed (green water), the 17 percent that requires irrigation (blue water) produces more than 40 percent of the world’s food supply.<sup>9</sup> The water needed for this part of agriculture amounts to a total of 70 percent of global water withdrawals.<sup>10</sup> 19 percent of global water withdrawals (blue water) is for industrial demands, including electricity production. Only 11 percent of water is used to meet municipal and domestic demands.

Figure 6 presents the shares of water use per sector at the global level.

**Figure 6: Global Water Withdrawals for Agricultural, Industrial and Municipal use**



Source: Aquastat, F.A.O. [http://www.fao.org/nr/water/aquastat/water\\_use/index.stm](http://www.fao.org/nr/water/aquastat/water_use/index.stm).

These percentages are global averages, but they vary significantly from country to country. In the United States for instance, irrigation amounts to 41% of the nation’s total freshwater withdrawals but industry uses up to 46% of water withdrawals, especially thermoelectric power generation, which needs enormous amounts of water cooling for the steam-driven turbine generators<sup>11</sup>. In the developing world, freshwater withdrawals are often mostly used for agriculture (86% in Egypt, 94% in Ethiopia, 95% in Vietnam).<sup>12</sup>

<sup>9</sup> Postel, 1999, p. 42.

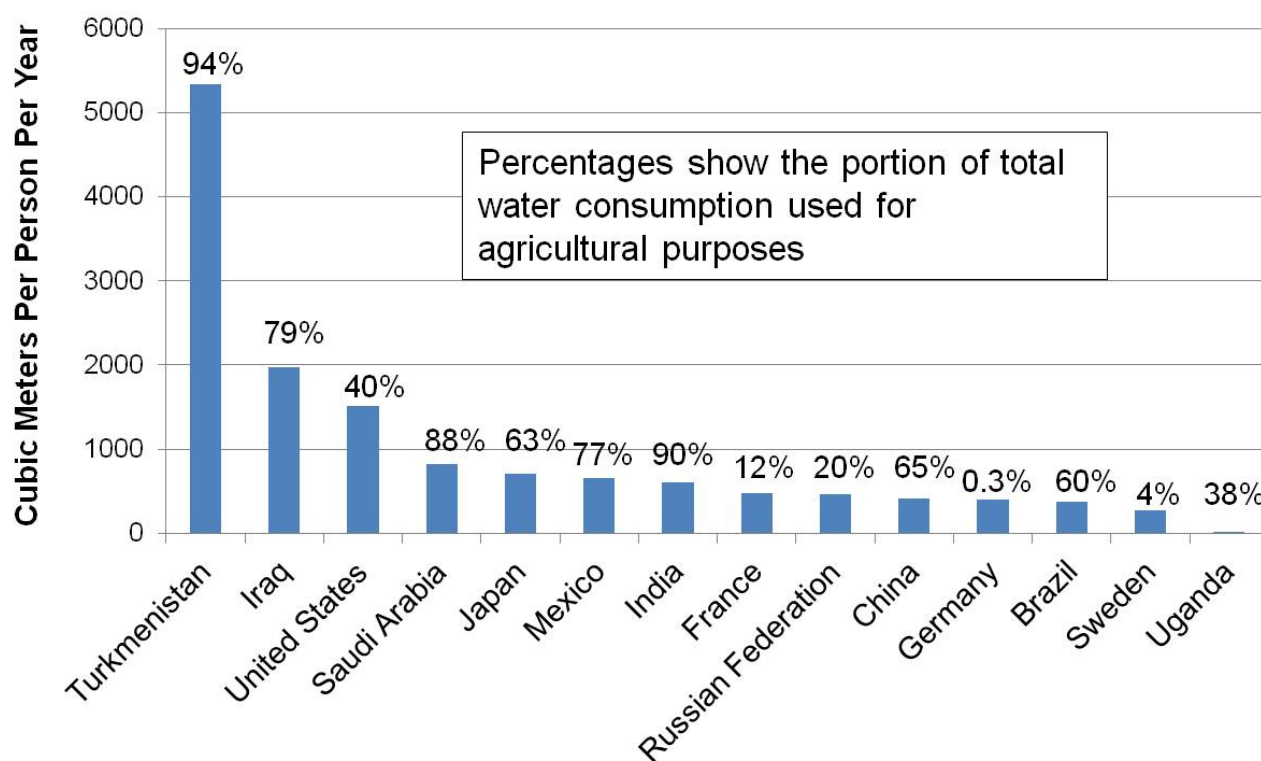
<sup>10</sup> Aquastat, Food and Agriculture Organization, [http://www.fao.org/nr/water/aquastat/water\\_use/index.stm](http://www.fao.org/nr/water/aquastat/water_use/index.stm).

<sup>11</sup> Gleick et al., 2014, p.227-235.

<sup>12</sup> *ibid.*

Like energy consumption, water consumption per capita varies significantly across different countries, as shown in Figure 7. Unlike energy use, water use is not mainly a function of economic development. Some countries with relatively high water use, such as Turkmenistan and Iraq, are not high-income countries yet heavily rely upon water for agriculture. While China has a higher gross domestic product (GDP) per capita than India, India uses more water per person, with 90 percent of it for agricultural purposes. German water use per-capita is similar to that in China, but hardly any water in Germany is used for agriculture.

**Figure 7: Water Consumption per Capita, Select Countries**



Source: World Bank Development Indicators, accessed on 8/21/15

While water itself is seldom traded, water is often used to produce goods that are traded. Countries can import goods produced with water coming from somewhere else, rather than with their own water resources.

To capture the impact of trade and total water consumption, two other indicators have been proposed: **virtual water** and **water footprint**.

1) **Virtual water** is the amount of water that is embedded in every single good or service, and which accounts for all of the water used as input at every step of the production process, either for agricultural goods, industrial goods, or services.<sup>13</sup>

<sup>13</sup> Concept and term coined by Tony Allan.

2) **Water footprint** builds on the concept of virtual water, aggregating actual and virtual water consumption to calculate the total water impact of a sector of activity, or of an individual, household, city, or country. It takes into account all types of water impacted – green, blue, and gray.<sup>14</sup>

## Virtual Water

In every good produced, there is a hidden quantity of water that has been used throughout the production process. Agricultural goods need water to grow plants and fruits, or water to raise cattle and other livestock. For instance, the production of an apple requires 70 liters of water, and the production of a glass of milk requires 200 liters of water (see Table 2). Industrial goods also require water from the raw material stage to the final production stage. One sheet of paper requires 10 liters of water to be produced, and a leather pair of shoes requires 800 liters. This hidden amount of water that is invisibly carried by any goods or products consumed is what we have defined as virtual water.<sup>15</sup>

**Table 2: Virtual Water embedded in a selection of products, per unit of product (in liters: 1 gallon = 3.78 liters)**

Product	Virtual-water content (liters)
1 sheet of paper (80 g/m <sup>2</sup> )	10
1 tomato (70 g)	13
1 slice of bread (30 g)	40
1 orange (100 g)	50
1 apple (100 g)	70
1 glass of beer (250 ml)	75
1 glass of wine (125 ml)	120
1 egg (40 g)	135
1 glass of orange juice (200 ml)	170
1 bag of potato crisps (200 g)	185
1 glass of milk (200 ml)	200
1 hamburger (150 g)	2,400
1 pair of shoes (bovine leather)	8,000

Source: Hoekstra and Chapagain, 2008, p. 15.

The energy sector consumes large amounts of water, which is used in all the different steps of energy extraction, production and consumption. Natural gas is the least water intensive fuel, whereas the use of unconventional oil tar sands requires 20 times more water than conventional oil and 100 times more water than natural gas. Biofuels are associated with high water consumption – 3,000 times more water than conventional oil! Table 3 presents the different amounts of virtual water that would be embedded in six types of fuel if they were used to power the same roundtrip New York City-Washington D.C. (requiring an amount of energy equal to 2 million BTUs – British Thermal Units).

<sup>14</sup> Concept coined by A. Hoekstra and P. Hung.

<sup>15</sup> Allan, 2011, p.9.

**Table 3: Virtual water used in six types of fuels, round trip New York City-Washington D.C.**

Type of fuel	Amount of water needed in the extraction/production of 2 Million BTUs of energy
Natural Gas (conventional)	5 gallons
Unconventional natural gas (shale)	33 gallons
Oil (conventional)	32 gallons
Oil tar sands (mining)	616 gallons
Biofuel type 1 (irrigated corn)	35,616 gallons
Biofuel type 2 (irrigated soy)	100,591 gallons

Source: World Policy Institute – EBG Capital analysis based on U.S. Department of Energy 2006, and World Economic Forum and Cambridge Energy Research Associates 2009. Available at: [http://www.worldpolicy.org/sites/default/files/policy\\_papers/THE%20WATER-ENERGY%20NEXUS\\_0.pdf](http://www.worldpolicy.org/sites/default/files/policy_papers/THE%20WATER-ENERGY%20NEXUS_0.pdf)

## Water Footprint

The concept of **water footprint**, based on the model of a carbon footprint<sup>16</sup>, was introduced by Hoekstra and Hung (2002) as an indicator that could map out the impact of all of human consumption on global freshwater resources. The water footprint shows the water use associated with consumption for an individual, institution, or country, including blue, green and gray water.

At the individual level, we can add up all the water needed to make food, energy and other products consumed. To calculate your own individual footprint, take the test at the website <http://www.gracelinks.org/1408/water-footprint-calculator>. The average person on the planet uses 1,056 gallons of water per day – that’s enough to fill up 21 standard bath tubs.<sup>17</sup> The average water footprint of an American consumer is 2,220 Gallons per day, which is the equivalent of 44 full bathtubs of water! Having a vegetarian diet or being a meat eater makes the biggest difference in a person’s water footprint, as you can observe by changing the options in the calculator. There is also an important connection between the carbon footprint and the water footprint. Increased use of energy tends to raise both carbon and water footprints (see Box 1).

Water footprint of nations can be calculated by taking into account all of the virtual water embedded in all sectors of economic activity, including agriculture, industries, services and domestic use.

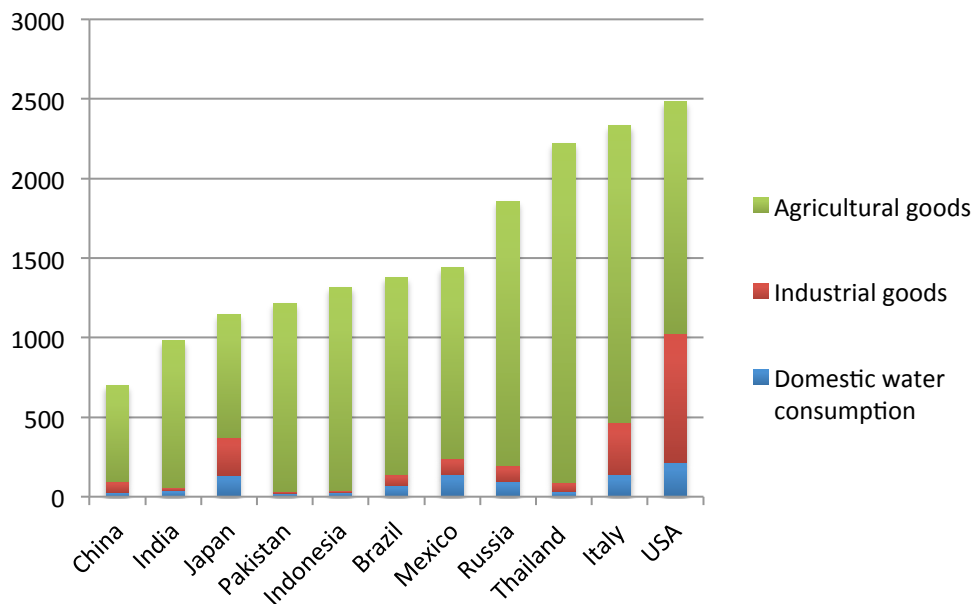
An important difference between the calculations of the traditional indicator of withdrawal per sector and the concept of water footprint is that the water footprint shows not only freshwater use within the country considered but also freshwater use outside the

<sup>16</sup> A carbon footprint measures the amount of carbon emissions associated with a given economic activity.

<sup>17</sup> Allan, 2011 p. 4, and <http://inhabitat.com/water-footprint-of-humanity-study-shows-average-person-uses-1056-gallons-of-water-each-day/>.

country's borders. It refers to all forms of freshwater use that contribute to the production of goods and services consumed by the inhabitants of a certain country. Figure 8 presents water footprints for a selection of countries.

**Figure 8: National Water Footprint for selected countries, 1997-2001**

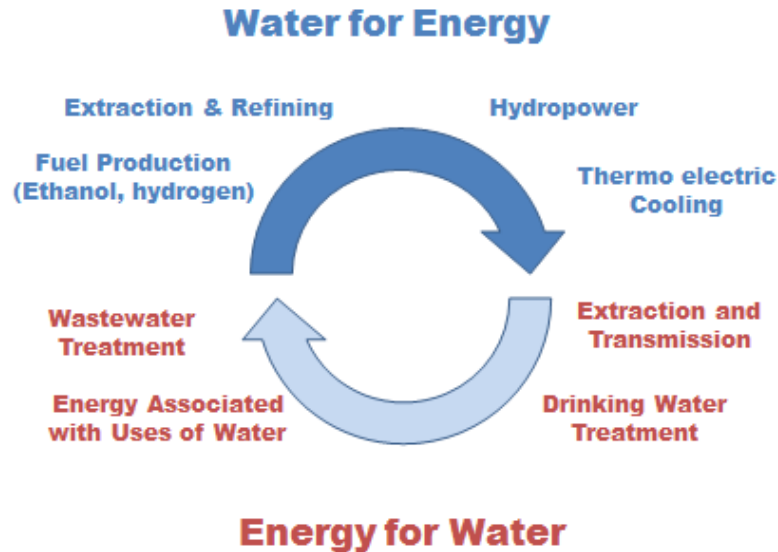


**Consumption in cubic meters per person per year**

Sources: Hoekstra and Hung, 2002, p. 60; also available at <http://waterfootprint.org/en/resources/interactive-tools/national-water-footprint-explorer/>

## Box 1: The Water-Energy Nexus

The demand for both water and energy is increasing while there are growing limitations on their supply. These two resources are closely connected. Water is itself a source of energy (hydropower) and water is an input to grow the crops used to make biofuels, and is also used in the extraction of fossil fuels (notably fracking gas and tar sands oil). At the same time, energy is necessary to pump and extract water, to clean and recycle it, and to desalinize sea water.



Water use in the energy sector primarily occurs in two areas: fuel production and electricity generation. Both of the processes can employ a number of different technologies that have very different water use requirements.

Water is used for pressure in drilling oil wells, especially in the nonconventional practices of fracking. Hydraulic fracturing or “fracking” involves pumping large volumes of water, mixing it with sand and chemicals, and sending it to the deep underground at high pressure to fracture the shale rock and release trapped gas. The exact chemical composition of fluids used by oil companies for fracking is unknown and undisclosed for reasons of industrial private intellectual property, which has generated controversy, because of their high toxicity and the risks of contamination of the water used in the process. According to Patrick Sullivan, of the California Center for Biological Biodiversity: “It is water that cannot be put back into the water cycle. It’s water that is by and large gone for good.” This contaminated water poses acute problems of storage to insure that it does not leak back into aquifers from which water is withdrawn for domestic use and for agriculture.

Sources: Aida Tabakovic & Elisabeta Poci, 2012, *The Water-Energy Nexus*, [http://www.cae.utexas.edu/prof/mckinney/ce397/Topics/Water-Energy/Water-Energy\(2012\)\\_ppt.pdf](http://www.cae.utexas.edu/prof/mckinney/ce397/Topics/Water-Energy/Water-Energy(2012)_ppt.pdf); <http://thinkprogress.org/climate/2015/04/06/3643184/california-70-million-gallons-fracking/>

The water footprint per capita of the United States is 2,500 cubic meters per person per year whereas the water withdrawal per capita is 1,500 cubic meters per person per year (Figure 7). The difference between the two figures reflects:

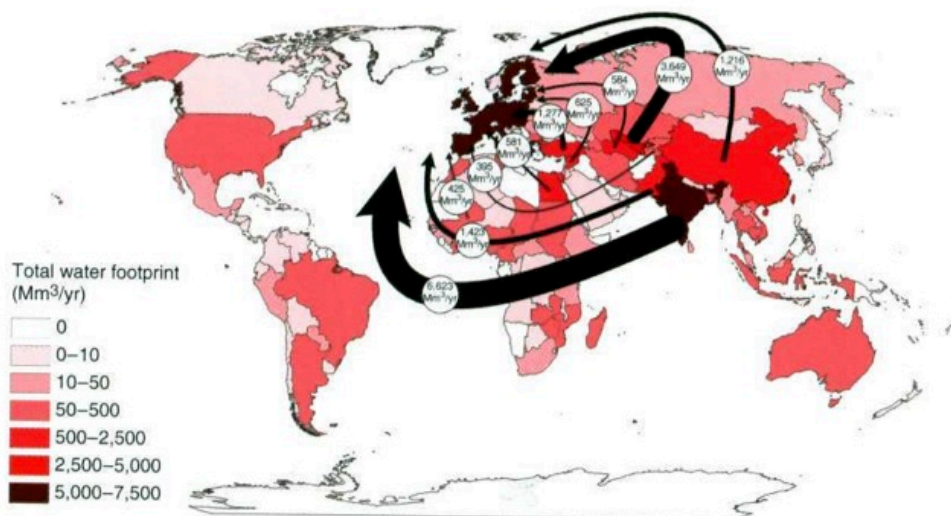
- 1) the water footprint takes into account all of the green water (primarily rain-fed crops) embedded in all the goods consumed in the US
- 2) the water footprint includes both an internal component, based on internal water resources, and an external component based on water used for imported products or ingredients.

### Virtual Water and Trade

There is an invisible circulation of water between countries that occurs through trade: water-scarce countries can consume imported products that would have been too water-consuming to produce in their own land. For instance, Saudi Arabian imports of milk and meat from Europe, Argentina or from Australia or New Zealand, allow Saudis living in a desert climate to have access to these goods, which is the equivalent of a water transfer from water-abundant countries to a water-scarce country.

But trade does not always follow a logical direction in terms of water transfer. Water-intensive crops such as cotton are often produced in water-stressed or even water-scarce countries for reasons that make little ecological sense. The virtual water embedded in a cotton T-shirt is 2,700 liters. However, cotton is produced in India and other Asian countries which are experiencing water stress/scarcity issues. Figure 9 shows the global picture of the import of cotton to Europe and what this trade implies in terms of water transfers.

**Figure 9: Virtual Water in Cotton Imports to the European Union (million m<sup>3</sup>/year), 1997-2001.**

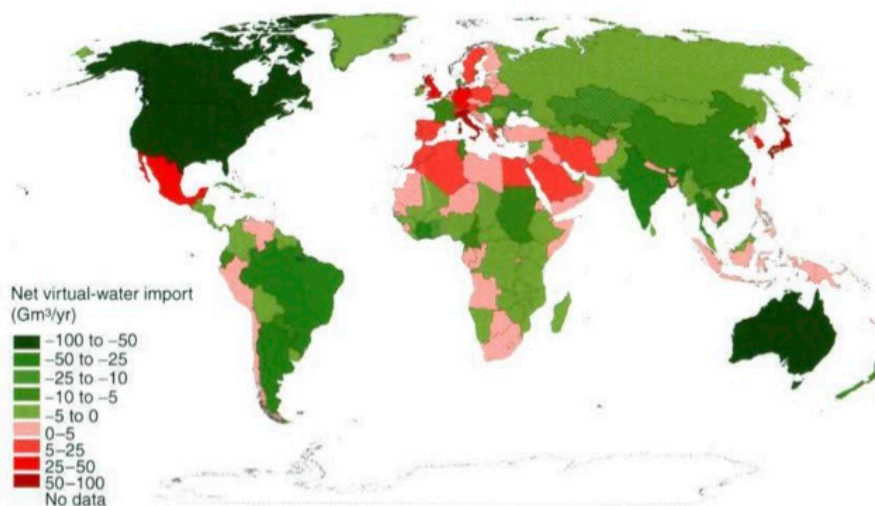


Source: Hoekstra and Chapagain, 2008, p. 85.

The production of cotton for export to Europe creates a water footprint of 5,000 to 7,500 million cubic meters in water-stressed India, and more than 2,000 million cubic meters in water scarce Egypt.<sup>18</sup>

Figure 10 shows the global picture of the amount of virtual water transferred through global trade, including both agricultural and industrial products. Countries that have a negative balance in virtual water trade (exporting goods that are more water intensive than the goods they import) are colored in green – they are net exporters of virtual water. Countries that have a positive virtual water balance are colored in red – they are net importers of virtual water.

**Figure 10: Virtual-water balance per country, 1997-2001 (billion cubic meters)**



Source: Hoekstra and Chapagain, 2008, p. 84-85.

If we compare this picture with Figure 3, we observe that many of the Asian countries that are experiencing water stress or near water-stress situations are actually virtual-water exporters. This is the case with India, Pakistan and China. On the other hand, there are countries that are relatively water abundant like Italy or Japan that nevertheless are virtual-water importers.

For water-scarce countries it can sometimes be attractive to import virtual water (through import of water-intensive products), thus relieving the pressure on domestic water resources. This happens, for example, in Mediterranean countries, the Middle East and Mexico. But the fact that Northern European countries import a lot of water in virtual form (more than they export) is not driven by water scarcity. In Europe as a whole, 40% of the water footprint lies outside of its borders.

<sup>18</sup> Hoekstra and Ashok, 2008, p. 131-135.



## **Water scarcity and conflicts**

Water scarcity can be a major factor leading to conflicts. For example, the civil war that has been raging in Syria since 2011 is strongly related to water shortage issues. A climatic event, the prolonged 6-year drought, from 2006 to 2011, ruined hundreds of thousands of small scale farmers, and forced them to emigrate to the outskirts of several cities such as Aleppo, Hama, Homs, Damascus and Dara'a, which became centers of political unrest against the Assad regime.<sup>19</sup>

In one of the most protracted conflicts of our times, between the State of Israel and the Palestinian people, access to the water aquifers underneath the hills of the West Bank constitutes one of the important factors. Although not generally discussed in the media, access to water has been a key factor in the occupation of the West Bank since 1967, including a growing number of controversial Israeli settlements that directly exploit this groundwater resource (See Box 2).

Scientists have modeled the impact of climate change on rain patterns in different regions of the world in the decades to come. Their results suggest that the Middle East and North Africa region would be subjected to more frequent and prolonged drought episodes.<sup>20</sup> In this already politically volatile region, the growing scarcity of water would likely contribute exacerbating future conflicts.

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<sup>19</sup> The World's water, volume 8. Peter Gleick, the Syrian conflict and the role of water, p. 147.

<sup>20</sup> World Bank Group, Turn down the heat, confronting the New Climate Normal, 2014. p. 125

## Box 2: Shared water aquifers for two people in conflict: the case of Israel-Palestine

As shown in the figure, Israelis and Palestinians rely on the same water aquifers for their needs but the rules that conduct how this common resource is shared are far from being equitable.



Source: <http://www.mediterraneanaffairs.com/en/events/water-israeli-palestinian-conflict.html>

A World Bank report indicates that Israelis use four fifth of the West Bank groundwater resources, and the Palestinians only one fifth.<sup>21</sup> Israelis use 240 cubic meters of water a person each year, against 75 cubic meters for West Bank Palestinians and 125 for Gazans. However, in Gaza, where Palestinians rely on an aquifer that has become increasingly saline and polluted, the situation is worse. Only 5%-10% of the available water is clean enough to drink.

In some areas of the West Bank, Palestinians are surviving on as little as 10 to 15 liters a person each day, which is at or below humanitarian disaster response levels recommended to avoid epidemics. The amount recommended by the World Health Organization is at least 100 liters per day.<sup>22</sup>

If the Palestinian inhabitants are to develop their country economically and socially in the future, they will have to be able to draw more heavily on this groundwater resource. This explains why this basin has been the most intensely disputed resource in every round of water negotiations between Israel and Palestine.

<sup>21</sup> Source: <http://www.theguardian.com/world/2009/may/27/israel-palestinian-water-dispute>  
<http://siteresources.worldbank.org/INTWESTBANKGAZA/Resources/WaterRestrictionsReport18Apr2009.pdf>  
World Bank Middle East and North Africa Region Sustainable Development, West Bank and Gaza Assessment of Restrictions on Palestinian Water Sector Development – Sector Note – April 2009

<sup>22</sup> See B'Tselem <http://www.btselem.org/topic/water>

## 2. ADDRESSING WATER SHORTAGES

To address water shortages, there are technical approaches that can alleviate the pressure on scarce resources by increasing the supply, or by decreasing the demand. There are also institutional approaches, including economic instruments, which can impact demand and keep it from growing beyond the necessary limits. Given the extent of projected water shortages in some regions, a “magic bullet” solution is unlikely. A range of options will be needed.

We have a menu of options, but the status quo is not one of them. In the United States, the usual response to water shortages is to divert more water from rivers, build more dams, and drill more groundwater wells. These traditional alternatives are not viable solutions. Other ideas—surreal ones—include towing icebergs from the Arctic, importing water from British Columbia, and seeding clouds. These ideas reflect a misguided hope that there is a new oasis out there, somewhere, that will obviate the need to examine carefully how and for what we use water. More sensible approaches include conservation, desalination, and reuse of treated municipal effluent. Yet even communities that have embraced these measures still face ominous water futures.<sup>23</sup>

### Increasing Water Supply: Aquifers, Dams, and Desalination

Past water management policies have generally focused on ways to increase the supply of water. In regions where freshwater supplies are insufficient to meet demand, additional water has often been obtained by extracting groundwater from aquifers. While underground aquifers are normally recharged by water seepage, in most cases withdrawal rates greatly exceed the rates of recharge.

Countries such as Saudi Arabia and Libya rely on “fossil” groundwater from ancient aquifers in desert areas, which have practically no recharge and are likely to be depleted over the next forty to sixty years. In the western United States, the Ogallala Aquifer is also severely depleted, and as a result irrigated area has started to shrink. Similar problems affect aquifers in North China and in India. (For more on the exploitation of aquifers around the world, see Box 3.)

Another way to increase water supplies is to construct dams. Dams can capture seasonal floodwater that would otherwise be unavailable for human use and use stored water to provide hydroelectric power. Worldwide close to 48,000 large dams are in operation, about half of them in China.<sup>24</sup> These dams provide 19 percent of the world’s electricity. More dams are still being built, mainly in China, Japan, Turkey, and Iran, but the best sites are already in use. Existing dams are often affected by problems of siltation, and new large dam proposals have been criticized for the environmental and social damage resulting from the flooding of large areas.<sup>25</sup> For example the Three Gorges Dam in China, the largest hydroelectric dam in the world, displaced 1.3 million people and disrupted the habitat of dozens of endangered species.

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<sup>23</sup> Gleick, 2011, p. xi-xii.

<sup>24</sup> Large dams are defined as those over 15 meters in height.  
[http://wwf.panda.org/what\\_we\\_do/footprint/water/dams\\_initiative/quick\\_facts/](http://wwf.panda.org/what_we_do/footprint/water/dams_initiative/quick_facts/).

<sup>25</sup> See World Commission on Dams, 2000.

### Box 3: Demand for Water Outstrips Supply

“Almost one-quarter of the world’s population lives in regions where groundwater is being used up faster than it can be replenished”, concludes a comprehensive global analysis of groundwater depletion.

Across the world, human civilizations depend largely on tapping vast reservoirs of water that have been stored for up to thousands of years in sand, clay and rock deep underground. These massive aquifers—which in some cases stretch across multiple states and country borders—provide water for drinking and crop irrigation, as well as to support ecosystems such as forests and fisheries.

Yet in most of the world’s major agricultural regions, including the Central Valley in California, the Nile delta region of Egypt, and the Upper Ganges in India and Pakistan, demand exceeds these reservoirs’ capacity for renewal.

‘This overuse can lead to decreased groundwater availability for both drinking water and growing food,’ says Tom Gleeson, a hydrogeologist at McGill University in Montreal, Quebec, and lead author of the study. Eventually, he adds, it ‘can lead to dried up streams and ecological impacts’.

The authors found that 20 percent of the world’s aquifers are being overexploited, some massively so. For example, the groundwater footprint for the Upper Ganges aquifer is more than 50 times the recharge rate of its aquifer, ‘so the rate of extraction is quite unsustainable there’, says Gleeson.

But Gleeson adds that there is at least one significant source of hope. As much as 99 percent of the fresh, unfrozen water on the planet is groundwater. ‘It’s this huge reservoir that we have the potential to manage sustainably,’ he says. ‘If we choose to.’”

Source: Mascarelli, 2012; <http://www.nature.com/news/demand-for-water-outstrips-supply-1.11143>

Because of the vast amounts of seawater on the planet, **desalination** (removing salt from seawater) has appeal as a potential source of virtually unlimited supply. However, cost is a significant barrier for desalination, which requires large amounts of energy. While desalination costs have declined as technology has improved, it currently costs about \$0.50 to \$1.00 per cubic meter to desalinate seawater, which is usually more expensive than obtaining water supplies from surface water or groundwater.<sup>26</sup>

For example, in an analysis of water supply options in San Diego, California, desalination costs were estimated to be \$1,800 - \$2,800 per acre-foot (AF)<sup>27</sup> while the supply costs were \$400 - \$800/AF for surface water and \$375 - \$1,100/AF for groundwater.<sup>28</sup> While desalination may make economic sense in some very dry regions, it is unlikely to supply a significant amount of the planet’s water in the future.

<sup>26</sup> WaterReuse Association, 2012.

<sup>27</sup> An acre-foot is an amount of water covering one acre one-foot deep. It is equivalent to 1,233 cubic meters.

<sup>28</sup> Equinox Center, 2010.

Despite major advancements in desalination technologies, seawater desalination is still more energy intensive compared to conventional technologies for the treatment of fresh water. There are also concerns about the potential environmental impacts of large-scale seawater desalination plants.<sup>29</sup>

## Water Demand Management

Water demand is projected to increase significantly (see Figure 15 in Section 5 below). One way to slow this demand increase is to increase water use efficiency. The greatest efficiency gains can be made in agriculture. Whereas traditional irrigation by flooding or channeling water by gravity is inefficient (60 percent of the water is lost by evaporation or infiltration), new techniques of **micro-irrigation** by drip systems allow an efficiency of 95 percent.<sup>30</sup> Also, technologies that permit better monitoring of soil and weather conditions can more accurately determine appropriate irrigation needs.

For nonagricultural uses, recycling and reuse of wastewater can reduce water demands. For example, through a graywater system, water used for such purposes as laundry and bathing can also be used to irrigate landscaping. Water use standards for devices such as dishwashers, toilets, and showerheads can reduce domestic water needs. Leak detection and repair, especially in municipal water supply lines, can also help reduce water consumption.

Economic research shows that conservation is generally the cheapest way to address water shortages. In the San Diego study mentioned above, the cost of conservation was estimated at between \$150 and \$1,000 per AF, based on a range of conservation options. The study concludes:

Conservation appears as the most attractive of the seven water solutions analyzed for San Diego County by a wide margin. These findings suggest that solving San Diego County's water challenge may rest significantly on the demand side.<sup>31</sup>

Water conservation can be realized using several approaches, including price-based and non-price approaches. Non-price approaches can be classified into four categories:<sup>32</sup>

1. *Required or voluntary adoption of water-conserving technologies*: This includes setting standards for appliance efficiency or offering water customers rebates or even free items such as low-flow showerheads.
2. *Mandatory water use restrictions*: These are often implemented in response to drought conditions and may include restrictions on watering lawns, washing cars, or filling swimming pools.
3. *Education and information*: These include mailing information to customers about ways to reduce water use, offering talks on water conservation, or airing public service messages on TV or the Internet.

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<sup>29</sup> Elimelech and Phillip, 2011, p. 712.

<sup>30</sup> Postel, 1992, Chapter 8.

<sup>31</sup> Equinox Center, 2010, p. 18.

<sup>32</sup> Olmstead and Stavins, 2007.

4. Water conservation can also come from *innovative institutional design of common-property resources*. This applies especially to communities of irrigators using the same aquifer or the same river basin water resource (see Box 4).

### **Water Governance: sustainable management of Common Property Resources**

Freshwater resources often present the characteristics of Common Property Resources (CPRs) - defined as rival (their use by one user reduces what is available to other users) and non-excludable (access to the resource is difficult to monitor). If the accessibility to the resource and the amount of water used by each user is left unregulated, a CPR can be overexploited and/or irreversible degraded.<sup>33</sup>

Facing such risks, two institutional solutions have been prevalently used in recent times: either governments have nationalized such resources, putting them under the supervision of civil servants responsible for their control; or these resources have been privatized, with the assumption that private owners would necessarily enforce sustainable practices of exploitation, in their own interest. Experience has shown that neither scheme is a panacea to avoid the risks of overexploitation. Bureaucracy can be ineffective in its control and civil servants can be corrupt and bribed. Private ownership is not either a guarantee against overexploitation: in the village of Plachimada, India, as in many other rural communities over the world, access rights to groundwater have been sold to multinationals such as Coca-Cola which have been mining the resource beyond its point of natural replenishment, resulting in dramatic consequences for small farmers relying on that resource for their livelihoods.<sup>34</sup>

However, the careful examination of historical cases has shown that, between privatization and governmental control, many other institutional solutions have existed across time and space. Nobel Economics Laureate Elinor Ostrom has observed that: "Communities have relied on institutions resembling neither the state nor the market to govern some resource systems with reasonable degrees of success over long periods of time".<sup>35</sup> Examples of such customary systems of collective water governance are presented in Box 4.

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<sup>33</sup> This inherent risk of overexploitation of Common-Property Resources has been called "the tragedy of the commons" in a famous article by Garrett Hardin (1968)

<sup>34</sup> S. Koonan, 2007.

<sup>35</sup> Elinor Ostrom, 1990, p.1

#### **Box 4: Collective systems of irrigation, from the Middle East, to Spain, to America**

Historical accounts of local collective systems of irrigation that proved sustainable over centuries are found in several societies around the world. For instance, the medieval archives of the city of Valencia, Spain, give the details of an ancient institutional example of great complexity, where the community of farmers managed their resource collectively. The farmers who shared the water of a single canal would come together to elect among themselves a syndic, whom had authority to monitor the canal and the amount of water allocated to each user – helped by a small staff of ditch-riders and guards. A system of turn was in place to ensure that every user would have access to the water alternatively. In periods of extraordinary drought, the procedures were modified so that farms whose crops were in the most need of water were given priority over farms whose crops required less water. The level of monitoring used was very high and included a Water Court (Tribunal de las Aguas) which was the ruling authority where any complaint on the actions of a syndic, a ditch-rider or another irrigator could be aired.

The term “as-saaqiya” which means “water conduit” or “the one that bears water” in Classical Arabic describes the water channels of irrigation, and became the Spanish “acequias”. Acequias evolved over 10,000 years in the deserts of the Middle East and were introduced into Southern Spain by the Moors during their nearly 800-year occupation. Spanish colonizers took Acequias to the New World, where they also found ancient indigenous systems of collective irrigation that Native Americans had developed for centuries. Tiwa Indians irrigated farmland as long as 1300 ago. The combination of the traditional irrigation techniques and collective governance of the Native peoples with the Acequias of the Spanish colonizers gave birth to the systems of irrigation found in the Indo-Hispano communities of the American West, notably in New Mexico (see picture).

Recent research have shed light on the reasons for the longevity and sustainability of Acequia agroecosystems, as they promote soil conservation and soil formation, provide terrestrial wildlife habitat and movement corridors; protect water quality and fish habitat, promote the conservation of domesticated biodiversity of heirloom crops, and encourage the maintenance of a strong land and water ethic and sense of place, among other ecological and economic base values.



*Acequias in New Mexico*

Throughout history, there seems to have been a strong correlation between the systems of governance of water systems and the general systems of political governance. The democratic rules necessitated by the collective management of commonly owned irrigation systems have pioneered ancient forms of democratic governance in many societies throughout the world.

Sources:

Elinor Ostrom, *Governing the Commons*, 1990. pp. 71-74

Arturo Sandoval, *Ancient Traditions keep desert waters flowing*, *Yes! Magazine*, May 13, 2010

<http://www.yesmagazine.org/issues/water-solutions/ancient-traditions-keep-desert-waters-flowing>

Recognizing the limits to both dominant models - national centralized control and privatization - a growing number of communities are turning towards models of collective governance. In doing so, they often take their inspiration from old traditional forms of common management of the water resource. In their broad historical diversity, schemes of collective management of CPRs increasingly serve as a blueprint in the design of future institutions for a sustainable management of water resources in the face of growing scarcities both in the developing world and in the industrialized nations, where no one can take water for granted any longer. This renewed approach advocates for a wise institutional crafting that democratically involves all share-holders and users of the resource in ways where they can exert control on each other and rely on accountable and transparent mechanisms of regulation and control.



### 3. WATER PRICING

Economists tend to focus on **water pricing** as the most effective way to induce water conservation. According to economic theory, prices should serve as indicators of economic scarcity, reflecting physical limits and environmental externalities. For various social and political reasons however, governments have often maintained artificially low water prices, particularly for agriculture. We now turn to a discussion of water pricing, in theory and in practice.

Water pricing relates to several important economic concepts. First we need to differentiate between value and price.<sup>36</sup> The value of water to consumers is reflected in willingness to pay for it. The difference between willingness to pay for water and its price is its net benefit, or consumer surplus. In theory, consumers will continue to purchase water as long as their willingness to pay for it exceeds the price. But this market analysis does not tell the whole story. While water has obvious use values, including for domestic uses and irrigation, it also has nonmarket and nonuse values, such as for recreation and wildlife habitat.

We must also differentiate between the average cost of supplying water and its marginal cost. The marginal cost is the cost of supplying one additional unit of water. The average cost is simply the total supply cost divided by the number of units supplied. The distinction is important because water utilities are normally **regulated monopolies**. A company seeking to maximize profits will produce as long as marginal revenue exceeds marginal supply costs (i.e., as long as it is making a profit on each unit). While an unregulated monopolist can set its price to maximize profits, a regulated monopolist such as a water utility is normally restricted in its ability to set prices.

Water utilities in the United States are either privately or publicly owned. Private water utilities are permitted to make a reasonable profit, while municipal utilities' prices are set to cover their total supply costs, considering both fixed and variable costs. In either case, regulatory bodies normally set water prices using **average-cost pricing**, without any consideration of marginal costs. For a municipal utility, setting price equal to average cost means that they will just break even.<sup>37</sup> A private utility would be allowed to charge a price somewhat above average cost in order to make a profit.

But does average cost pricing result in an efficient level of water supply? We know that the socially efficient level of provision for a good occurs where marginal benefits equal marginal costs. Thus average-cost pricing is unlikely to result in an efficient level of water supply. Normally the marginal cost of water supply is quite low relative to its average cost because supplying water requires significant up-front capital costs, such as for pipes and treatment facilities. This might seem to imply that the efficient price for water should be lower than its average cost. But we also need to consider the externality costs of supplying water, which may include such impacts as the loss of wetlands and wildlife habitat. For a socially efficient price, any externality costs should be considered when calculating the average cost of supply. In this respect, failing to account for water's externality costs

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<sup>36</sup> See Hanemann, 2005, for a discussion of the value and price of water.

<sup>37</sup> See Carter and Milton, 1999.

implies that average-cost pricing may result in a price that is too low. So it is unclear whether average-cost pricing results in a price that is too high or too low from the perspective of economic efficiency.

For the management and pricing of groundwater, a nonrenewable resource, its efficient allocation over time requires us to take into account the externality costs imposed on future generations if future supplies will be insufficient to meet their demands. These costs can be internalized by charging a user cost to the current generation. This is rarely done in practice for groundwater, again suggesting an inefficient allocation of water.

Further complicating our analysis is the fact that water is often subsidized by the government, in particular for irrigation uses.

Many authors have called for the elimination of irrigation subsidies, at times suggesting that water is a commodity and should be priced accordingly. They describe the potential gains in irrigation efficiency and the public value of communicating scarcity conditions through market-based prices. Other authors suggest that subsidies can be justified because irrigation projects provide both public and private goods, or that higher water prices will reduce agricultural net revenues without motivating notable reductions in irrigation diversions.<sup>38</sup>

In regions where irrigation results in significant environmental impacts, it may be more appropriate to tax water rather than subsidize it. Consider some of the environmental damages caused by irrigation:

An excessive withdrawal of water for irrigation is clearly impacting the environment in some areas. For example, the Colorado River often contains essentially no water by the time it crosses the border into Mexico, owing to both urban and agricultural withdrawals. In fact, in most years, the Colorado River doesn't make it to the ocean. This has consequences for the river and its riparian ecosystems,<sup>39</sup> as well as for the delta and estuary system at its mouth, which no longer receives the recharge of fresh water and nutrients that it normally did. The same is true for the Yellow River in China. The San Joaquin River in California is so permanently dewatered that trees are growing in its bed and developers have suggested building housing there. In the last 33 years, the Aral Sea has lost 50 percent of its surface area and 75 percent of its volume, with a concomitant tripling in its salinity, owing largely to diversion of water from its feeding rivers for irrigating cotton.<sup>40</sup>

A supply and demand graph helps to illustrate the inefficiency of subsidizing irrigation water, especially when its withdrawal and use have negative externalities. In Figure 11, the market equilibrium for irrigation water occurs where the marginal cost curve (MC) intersects the demand curve, resulting in a price of  $P_E$  and a quantity of  $Q_E$ . But suppose that irrigation is subsidized such that its price is  $P_S$ , below the equilibrium price. The quantity sold will increase from  $Q_E$  to  $Q_S$ .

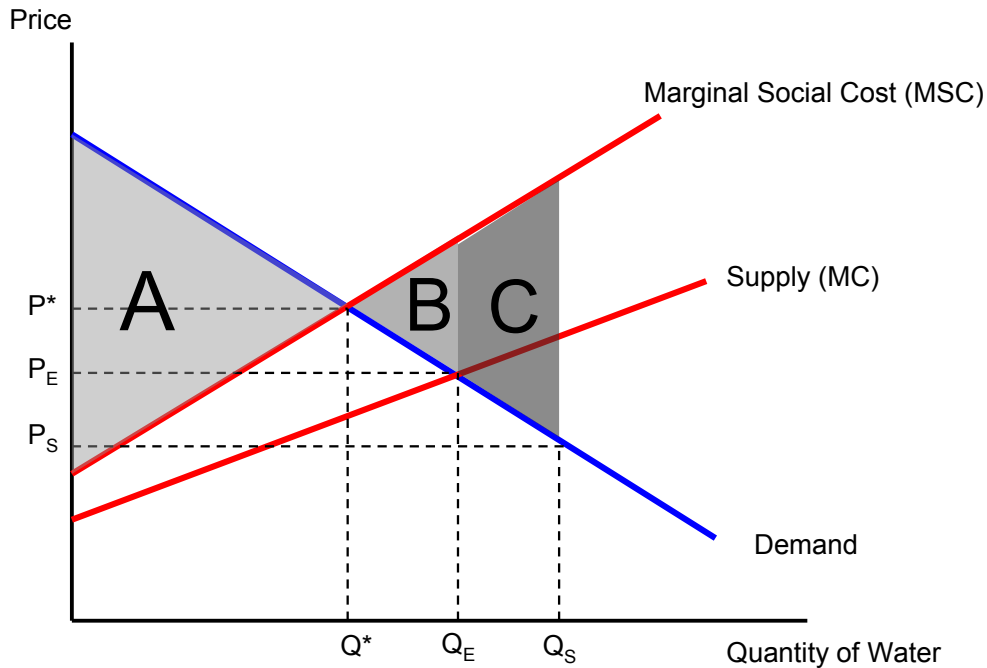
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<sup>38</sup> Wichelns, 2010, p. 7.

<sup>39</sup> "Riparian" refers to the banks of a river or watercourse. See discussion of Riparian water rights, Section 4.

<sup>40</sup> Stockle, 2001, p. 4-5.

**Figure 11: Effects of Subsidizing Irrigation Water**



In order to analyze the welfare effects, we also need to account for the negative externalities. The true marginal social cost of irrigation water is represented by the curve MSC, which includes the externality costs. For every unit above  $Q^*$ , the marginal social cost exceeds the marginal benefit (recall that the demand curve indicates the marginal benefits).

Area A represents the amount of net benefits of irrigation water at a quantity of  $Q^*$ . In other words, it is economically efficient to supply irrigation water up to  $Q^*$ . At the market equilibrium,  $Q_E$ , the net social welfare would be  $(A - B)$ . At the subsidized quantity,  $Q_S$ , the net social welfare would be  $(A - B - C)$ , a lower level of social welfare than at the market equilibrium. B and C represent areas of net loss resulting from failure to internalize negative externalities from subsidizing the price of water.

In this example, the maximum social welfare would be obtained at a quantity of  $Q^*$ . We could obtain this level of welfare by taxing water, instead of subsidizing it.

So far we have discussed water as if it has a single price. But the price of water (or “water rate”) varies in several respects. First, the price of water normally depends on its use. Specifically, water prices charged by utilities are different for domestic, agricultural, and industrial users. The cost of agricultural water in the United States is approximately \$5 - \$100 per thousand cubic meters.<sup>41</sup> Meanwhile, a typical household monthly water bill is about \$20 - \$120 per month, which equals a cost of about \$400 - \$2,500 per thousand cubic meters.<sup>42</sup>

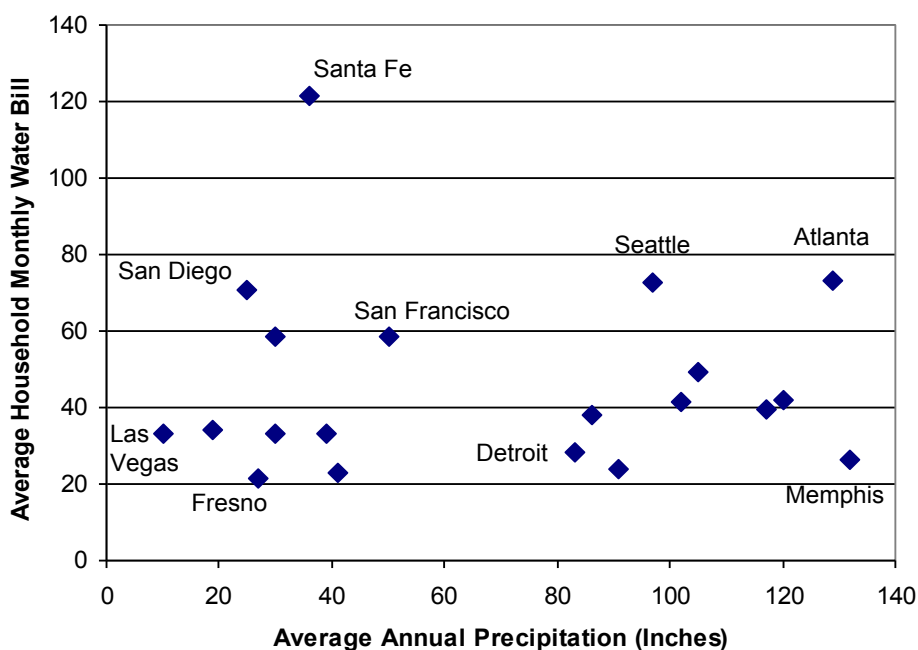
<sup>41</sup> Wichelns, 2010.

<sup>42</sup> Walton, 2010.

While it may initially seem inefficient, and perhaps unfair, to charge different users different rates, there is some justification for charging agricultural and industrial users less than households. Household water requires a high degree of treatment because it must meet drinking water standards. Irrigation water is not required to meet the same quality standards and thus is cheaper to supply. After use, domestic water must also be removed for treatment. In many municipalities, households are charged a separate “sewer rate” for water disposal in addition to a charge for their water supply.

The price ranges presented above indicate that the price of water can vary regionally. Figure 12 shows the average monthly water bill in different American cities presented in relation to average precipitation.<sup>43</sup> We might expect that water prices would be highest where water is the most scarce (i.e., precipitation is the lowest). While some arid cities, such as Santa Fe and San Diego, do charge high water rates, other dry regions, such as Las Vegas and Fresno, charge very low rates. This reflects the kind of government subsidy for water discussed in the example above.

**Figure 12: Average Monthly Water Bill vs. Precipitation in U.S. Cities**



Source: Walton, 2010.

Water rates in relatively wet cities can also vary considerably. In fact, there seems to be no discernible relationship between water rates and precipitation. Of course, other factors determine water availability besides precipitation. Water is relatively cheap near the Great Lakes because they provide a low-cost supply of water. Some cities may have access to sufficient groundwater while others may not. Some cities can store water in reservoirs to keep supplies relatively constant throughout the year.

<sup>43</sup> Water bill based on a family of four using 100 gallons per person per day.

Water prices are generally rising, particularly in regions where supplies are scarce and population is increasing. Additional supplies can often be obtained only by relying upon relatively expensive sources such as desalination. As water levels in underground aquifers fall, pumping becomes more expensive. As mentioned earlier, the alternative to obtaining additional supplies is to manage demand. By raising prices, utilities send consumers a signal about the increasing scarcity of water.

Higher water prices will induce a behavioral response among households and other water users. Irrigators are more likely to invest in efficient irrigation methods. Households are more likely to purchase low-flow showerheads and wash cars less frequently. But how much will water users reduce their water consumption in response to higher rates? This depends on the **price elasticity of demand**, which is defined as the responsiveness of the quantity demanded to price, equal to the percentage change in quantity demanded divided by the percentage change in price:

$$\text{Elasticity of demand} = \frac{\text{Percent change in demand}}{\text{Percent change in price}}$$

The elasticity of demand for water tends to be inelastic, meaning that the percent change in the quantity demanded tends to be smaller in absolute value than the percent change in price.

A significant amount of research has been conducted to estimate the elasticity of demand for water, particularly for residential users. A 2003 meta-analysis identified more than 300 elasticity estimates from 64 studies.<sup>44</sup> The mean elasticity was -0.41, with a median of -0.35. A meta-analysis of studies on irrigation water found a mean elasticity of -0.51 and a median of -0.22, based on 53 estimates.<sup>45</sup> A review of several studies on industrial water use finds that the elasticity varies considerably across different industries, ranging from about -0.10 to -0.97.<sup>46</sup> As expected, water demand also tends to be more elastic in the long run than in the short run.

Based on these estimates, water managers can determine how to adjust the price to meet conservation objectives. For example, suppose that a water utility is experiencing a potential water shortage and needs to lower water usage by 10 percent: If the elasticity of demand is -0.41, then the water utility would need to raise price by 41 percent to achieve a 10 percent reduction in quantity demanded.

But the relationship between water demand and price is not as simple as this example. One reason is that elasticity is not constant across regions or seasons. In the meta-analysis of residential water mentioned above, water demand tends to be more elastic in arid Western states than in the eastern United States. Also, water demand tends to be less elastic in winter months than in summer months. In the summer, more water use is for relatively non-essential uses such as irrigating lawns and washing cars. In the winter, a higher percentage of total water use is for more essential tasks, such as bathing

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<sup>44</sup> Dalhuisen et al., 2003.

<sup>45</sup> Scheierling et al., 2004.

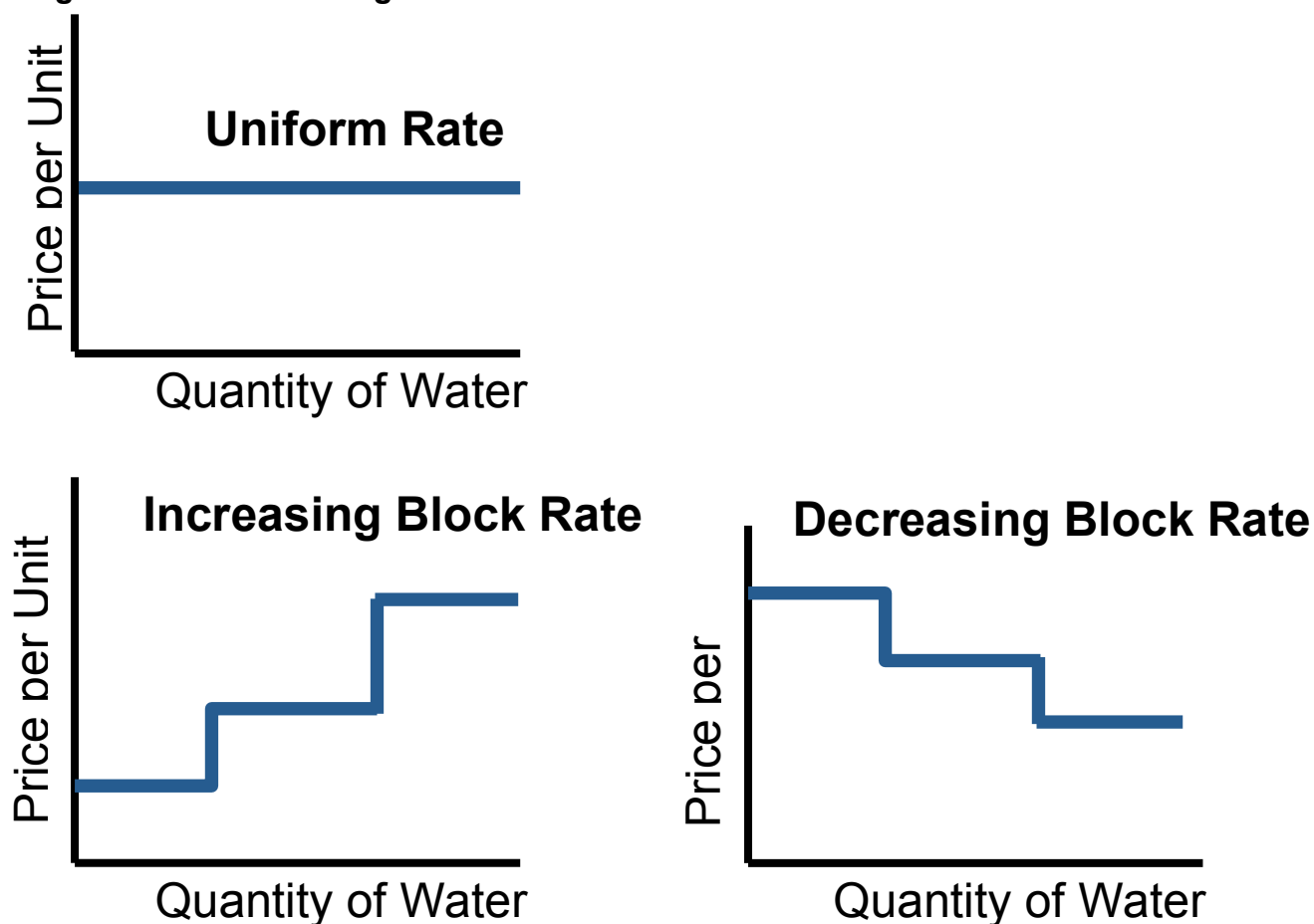
<sup>46</sup> Olmstead and Stavins, 2007.

and washing dishes. So in the summer, households can more easily reduce water use in response to a price increase.

Another complication in pricing water is that water is commonly not sold at a constant price per unit. In some cases, water users simply pay a flat monthly fee and then are able to essentially consume all the water they wish with no marginal increase in cost. While rare in the United States, in some countries, including Canada, Mexico, Norway and the United Kingdom, water is not normally metered.<sup>47</sup> Where water usage is metered, there are three basic pricing structures, as illustrated in Figure 13:

- **Uniform Rate Structure** – The price per unit of water is constant regardless of the amount of water used.
- **Increasing Block Structure** – The price per unit of water increases as the amount of water used increases. The price is constant within each block, but the price per unit is higher for successive blocks.
- **Decreasing Block Structure** – The price per unit of water decreases as the amount of water used increases.

Figure 13: Water Pricing Structures



<sup>47</sup> OECD, 2009.

An increasing block structure encourages more water conservation, as water users will wish to avoid moving into the higher priced blocks. The rationale behind a decreasing block structure is that it provides a price break for large water users, typically for commercial or industrial users. Water may also be priced differently by season, with rates normally higher during the summer season to discourage nonessential water consumption.

In the past, decreasing block rate structures used to be the most common pricing method for public water supplies in the United States.<sup>48</sup> As concerns about water conservation have grown, increasing rate block structures have now become the most common approach. In 2008, 32 percent of U.S. public water systems used uniform rates, 28 percent used decreasing block rates, and 40 percent used increasing block rates.

Internationally, rate structures vary widely. An international survey of water utilities found that in OECD countries, 49 percent used increasing block pricing, 47 percent used uniform rates, and only 4 percent used decreasing block rates. For non-OECD countries, 63 percent of water utilities used uniform pricing, and nearly all others used increasing block pricing.<sup>49</sup>

While an increasing block structure tends to promote higher rates of water conservation, other factors are also relevant when determining which rate structure and prices to adopt. Other considerations include:

- Utility rates are regulated; thus utilities cannot simply raise rates to induce a specific amount of conservation.
- Raising water rates disproportionately impacts low-income households. Thus utilities may also try to take equity into consideration when setting water rates. In South Africa, the right to “sufficient water” is written into their constitution. This is operationalized by making the first block of water free (successive blocks are normally charged using an increasing block structure) so that even poor households can afford a baseline amount of water.
- Increasing block structures are somewhat more difficult to understand. Users should clearly understand when their usage moves into higher-priced blocks.
- Finally, raising water prices or changing the water rate structure may be politically difficult. While involving customers in rate discussions can increase support for conservation programs, utilities need to balance political feasibility with conservation objectives.

As the western States of the US are experiencing frequent droughts, many large cities have opted for a tiered-pricing system in which residents who use more water pay higher rates than those who use less (see Box 5). Santa Fe, New Mexico, raised its rates the most in response to a drought. The tiered approach has worked as intended. Since 2001, Santa Fe’s total water consumption has dropped by a fifth, even as the high desert city’s population has increased more than 10 percent. In Santa Fe per-capita water usage has plunged, falling from nearly 140 gallons a day in 2001 to about 100 now.<sup>50</sup> Figure 14

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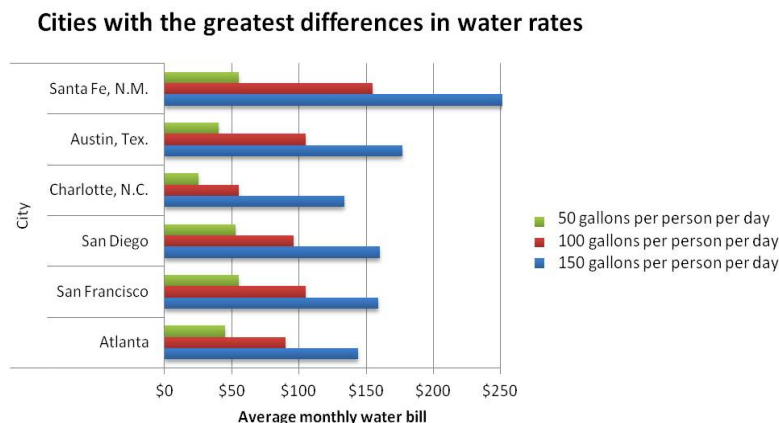
<sup>48</sup> Tietenberg and Lewis, 2012.

<sup>49</sup> OECD, 2009.

<sup>50</sup> New York Times, “Water Pricing in Two Thirsty Cities”, 2015.

shows the difference in water bills for 3 types of consumption (50, 100, 150 gallons a day) in some of the cities implementing tiered-pricing and feature some of the greatest differences in water rates.

**Figure 14: Water rates for Selected U.S. Cities**



Source: NY Times <http://www.nytimes.com/2015/05/07/business/energy-environment/water-pricing-in-two-thirsty-cities.html>

The high prices for higher quantities of water used seem not to affect the wealthiest households who can afford paying high water bills and can continue therefore to use large and wasteful amounts of water. This makes even more visible the social and economic inequalities between rich and poor, translating them in terms of unequal access to water (see Box 5).

**Box 5: Water pricing and social inequalities**

The four-year drought that started in 2011 in California, has led several counties to adopt increasing block rate structures, with several tiers. But this structure has been criticized both on social and legal grounds. As expressed by Stephanie Pincetl, the director of the California Center for Sustainable Communities at the University of California, Los Angeles:

"The wealthy use more water, electricity and natural gas than anyone else. They have bigger properties. They are less price sensitive. So if you can afford it, you use it. Then it becomes a moral question, but lots of wealthy people don't pay their own bills, so they don't know what the water costs."

In addition to exacerbating social inequalities, this pricing system in tiers is also legally challenged:

"the legality of conservation -- the practice of charging higher water rates to people who consume more for big water use -- came under question when a court ruled that a tiered-pricing system used by an Orange County city ran afoul of the State Constitution and sent it back to allow the city to try to bring it into compliance."

Source: New York Times, April 27, 2015: "Drought frames economic divide of Californians".

<http://www.nytimes.com/2015/05/07/business/energy-environment/water-pricing-in-two-thirsty-cities.html>.



## 4. WATER MARKETS AND PRIVATIZATION

An economically efficient distribution of water implies that water should be allocated toward uses that generate the highest marginal values (i.e., the highest willingness to pay). In theory, transferring water from low-valued uses to higher-valued uses increases overall social welfare. At the efficient allocation, the marginal value of water would be constant across different uses, such that further transfers would not clearly result in a net increase in overall welfare.<sup>51</sup>

Table 4 provides estimates of the marginal value of water for several different uses, based on a review of existing studies from the mid-1990s in the United States. We see that the value of water can vary significantly among uses—highest for industrial and domestic uses, lowest for generating power and recreation/wildlife.<sup>52</sup> These uses are not all mutually exclusive. For example, water could be used for recreation and then further downstream for irrigation.

The table suggests that there may be some potential for reallocating water from relatively low-valued uses to higher-valued uses. However, the allocation of water in the United States and elsewhere is rarely determined by concerns about economic efficiency. Instead, water rights are allocated based on various historical and legal considerations.

**Table 4: Marginal Value per Acre-Foot of Water in Various Uses**

<b>Water Use</b>	<b>Average Value per AF</b>	<b>Median Value per AF</b>
Navigation	\$146	\$10
Recreation/Wildlife Habitat	\$48	\$5
Hydropower	\$25	\$21
Thermoelectric Power	\$34	\$29
Irrigation	\$75	\$40
Industrial	\$282	\$132
Domestic	\$194	\$97

Source: Frederick, et al., 1996.

In the eastern United States, water rights are commonly allocated based on **riparian water rights**. Under this doctrine, the right to reasonable use of water is given to those who own the land adjacent to a water source. Where demands exceed the available water supply, rights may be allocated based on the amount of water frontage of each owner. Riparian water rights generally do not allow for irrigation withdrawals or the transfer of water to lands nonadjacent to bodies of water.

While riparian water rights were initially applied in the western United States, by the late 1800s the water demands of agriculture and mining necessitated a different water

<sup>51</sup> As mentioned earlier, we would need to account for differences in water quality. The marginal WTP for residential water would not be equal to the marginal WTP for irrigation water at the efficient allocation because the water quality needs of these users differ.

<sup>52</sup> Note that a large difference between the average and median values indicates that a relatively small number of particularly large estimates shifts the average upward.

rights system. **Prior appropriation water rights** separate the right to water from land ownership. Under this system, a right to water is recognized when someone establishes a **beneficial use** for it, such as for irrigation or municipal use. This system is also called “first in time, first in right” because rights are assigned on the basis of when a beneficial use first occurs.

Say, for example, that a farmer begins to withdraw 1,000 AF of water per year from a river. Then suppose several years later a factory wishes to withdraw 5,000 AF per year from the same river. The farmer would be recognized as the “senior appropriator” and the factory (the “junior appropriator”) would only have access to water after the farmer takes 1,000 AF. Anyone else who starts to withdraw water after the factory has established its right could still establish a prior appropriation right, but only after both the farmer and factory have taken their full allotment. In the case of a drought, if only 3,000 AF were available from the river, the farmer could get his or her full allocation of 1,000 AF, the factory would get the remaining 2,000 AF, and any other more-junior water users would get nothing.

Obviously, the doctrine of prior appropriation doesn’t allocate water in an economically efficient manner. In fact, it tends to discourage conservation because if senior water right holders start using less than their full allocation, over time the amount of water associated with their rights could be legally reduced. Also, prior appropriation rights tend to make no allowance for ecological needs. Thus in the case of water shortages, ecosystems may suffer significant damage.

The creation of **water markets** has been proposed as a way to increase the economic efficiency of water allocation in the presence of prior appropriation rights. In a water market, water right holders can sell some of their water to willing buyers. One example is a farmer who sells some of his or her water to a municipality. The municipality might buy the water in a one-time purchase (referred to as a lease) or could buy the actual water rights, which would establish it as the senior appropriator for a given amount of water per year.

As in any other market transaction, a water market in theory increases social welfare because both the buyers and sellers perceive that they will benefit from the transaction. But efficiency gains may need to be weighed against the impact of water markets on existing inequities. If poor people hold secure water rights, then water markets could provide an additional source of income. More likely, though, is that water could be directed away from the needs of the poor toward profitable uses by large-scale farmers, corporations, or other interests. For example, water markets were established in Chile in the early 1980s but led to higher water prices as a result of speculation and the monopolization of water rights. In 2005 the Chilean water market laws were revised to limit the potential for speculation and monopolization.

A water market does not necessarily require the direct transportation of water. An upstream water right holder could easily sell her rights to a downstream user. The upstream right holder would simply withdraw less water, allowing the downstream user to withdraw more. The sale of water rights from a downstream user to an upstream user could also be conducted similarly. But in some cases a water sale may require water to be transported through canals or pipes.

A fairly complex system for water transfers has already been established in the western United States. The California State Water Project and the Central Arizona Water Project are examples of engineering projects that transport water hundreds of miles to its final users.

The conditions necessary for a successful water market to form have been identified as:

- Water rights must be clearly defined.
- Water demand must exceed water supply. There must be some water users or potential users who are unable to obtain all water they seek at prevailing prices.
- Water supplies must be transferable to where water is desired for purchase and available when it is needed. Also, transaction costs must be relatively low.
- Water buyers must be confident that purchase contracts will be honored, with appropriate regulation and oversight.
- A system must be in place to resolve conflicts. This could involve both legal proceedings and less-formal resolution options.
- The cultural and social context must be considered. Some regions may resist water markets if most people believe water is not a salable commodity.<sup>53</sup>

Water markets are in place in several countries, including Australia, Chile, South Africa, the United Kingdom, and the United States. An analysis of water markets in the United States identified about 1,400 water sales between 1990 and 2003.<sup>54</sup> Most of the water volume transferred involved short-term leases rather than outright purchases of water rights. Municipalities were the most common purchaser of water (normally from irrigators), but transfers between irrigators were also common.

About 17 percent of the water purchased was for environmental purposes, including purchases by municipalities and environmental organizations. The potential for water market transfers to meet environmental objectives, such as maintaining sufficient in-stream flows for wildlife habitat, is receiving increased attention. Some analysts see great potential for water markets to improve the environment:

Overcoming [barriers to water market trades] is an increasingly important challenge as populations and western economies continue to grow. With this growth comes increasing demands for environmental and recreational amenities. ... Removing barriers to trade will reduce transaction costs, promote more efficient water allocation among offstream and instream uses, create incentives for improved water use, and improve environmental quality.<sup>55</sup>

Even where environmental values exceed the values of other water uses, the proper institutions must exist to obtain the necessary funding. Voluntary contributions to environmental organizations can raise some funds to purchase water rights, but the presence of free riders means that environmental water purchases will be undersupplied to society. Also, water markets can harm as well as help the environment. Water transfers

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<sup>53</sup> Conditions adapted from Simpson and Ringskog, 1997.

<sup>54</sup> Brown, 2006.

<sup>55</sup> Scarborough, 2010, p. 33.

can degrade water quality and excessively deplete aquifers.<sup>56</sup> And as in any market, negative externalities may require government intervention to internalize the externalities.

## Water Privatization

A related issue is whether water should be supplied as a public good by government agencies or as a commodity by private companies<sup>57</sup>. **Water privatization** has been promoted by international organizations such as the World Bank and International Monetary Fund on the grounds that private companies can provide more efficient and reliable service than public entities, particularly in developing countries. In theory, if a private company can provide water at a lower cost, then these cost savings can be passed on to customers, and perhaps more people can obtain access to water. But without appropriate regulation a private company may be able to charge excessive rates or fail to address the water needs of low-income households.

Water privatization has occurred, to some extent, in many countries, including Brazil, China, Colombia, France, Mexico, and the United States. The experience with water privatization has been mixed. According to the World Bank, water privatization in Manila, Philippines, has been successful in expanding water supplies to poor households:

By expanding the provision of reliable and affordable services to customers, the program has benefited some 107,000 poor households since its inception in 1997. Near-to-regular access to potable/piped water supplies and increased community sanitation facilities has been achieved in low-income residential centers. Furthermore, the program established customer facilities to encourage communities to discuss and participate in the process of expanding services, and to resolve their concerns.<sup>58</sup>

However, in other cases water privatization has failed to deliver on its promises. Perhaps the most dramatic example was the experience in Bolivia (see Box 6).

Water markets and privatization are clearly not a universal panacea for water problems. The tide to privatization seems to have turned at the global level:

“A report by the Transnational Institute (TNI), Public Services International Research Unit and the Multinational Observatory suggests that 180 cities and communities in 35 countries, including Buenos Aires, Johannesburg, Paris, Accra, Berlin, La Paz, Maputo and Kuala Lumpur, have all “re-municipalized” their water systems in the past decade. More than 100 of the “returnees” were in the US and France, 14 in Africa and 12 in Latin America. Those in developing countries tended to be bigger cities than those in richer countries.”<sup>59</sup>

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<sup>56</sup> Chong and Sunding, 2006.

<sup>57</sup> As discussed previously, water resources have also been customarily considered as Common Property Resources by countless societies and communities throughout history and all over the world, who have governed this water according to institutional rules that resembled neither the State nor the market, as observed by Elinor Ostrom.

<sup>58</sup> World Bank, 2010, page 2.

<sup>59</sup> “Water Privatization: a worldwide failure?” The Guardian, January 30, 2015.

Leading the remunicipalization trend are countries with a long history of private water management. “It is no accident that France, the country with the longest history of water privatization and the home to the leading water multinationals, presents so many cases of remunicipalization. French local authorities and citizens have experienced first-hand the “private management model” that Veolia and Suez have exported around the world. In the past few years many French cities have decided to follow in the footsteps of Grenoble and Paris and take back control of the water system.”<sup>60</sup> Remunicipalization can improve access and quality of water services, and also offers opportunities to build democratic governance, strengthening accountability and transparency.

Although the World Bank and other international financial institutions are still promoting privatization under all its forms, water markets and privatization cannot be considered as the unique solution that solves all problems. The challenge is to ensure that markets and privatization operate in a manner to meet broader social and environmental goals, rather than simply maximize profits. For more on this debate, see Box 7.

#### **Box 6: Bolivia Water Wars**

In Bolivia, in the city of Cochabamba, the municipal water company SEMAPA was sold in the late 1990s to a transnational consortium controlled by U.S.-based Bechtel in exchange for debt relief for the Bolivian government, and for new World Bank loans to expand the water system. A new law allowed this consortium, Aguas del Tunari, to administer not only the water resources that were under the control of SEMAPA but also communal water systems. Local farmer-irrigators feared that “even the rain” collected and distributed for centuries by their local associations would fall within Bechtel’s grasp.

These concerns, along with a 50% average increase in water rates for customers, prompted the formation of a broad alliance of farmers, factory workers, rural and urban water committees, neighborhood organizations, students, and middleclass professionals in opposition to water privatization. After several weeks of civil disobedience and angry protest in the streets, popular pressure forced the Bolivian government into negotiating the abrogation of the contract with Bechtel and returning SEMAPA to public control.

Sources: “The politics of water in Bolivia” <http://www.thenation.com/article/politics-water-bolivia>; “From water wars to water scarcity: Bolivia’s cautionary tale” <https://nacla.org/blog/2013/6/5/water-wars-water-scarcity-bolivia%E2%80%99s-cautionary-tale>

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<http://www.theguardian.com/global-development/2015/jan/30/water-privatisation-worldwide-failure-lagos-world-bank>; Transnational Institute, 2015, p.3

<sup>60</sup> Ibid. p.5

### **Box 7: The New Oil: Should Private Companies Control our Most Precious Natural Resource?**

Nearly everyone agrees that global water supplies are being used unsustainably. Can privatization lead to more sustainable practices, with market prices motivating water conservation?

Privatization of water supplies has traditionally been implemented in developing countries. In the late 1990s the World Bank pushed scores of poor countries to privatize their water supplies as a condition for receiving desperately needed economic assistance. In several cases, most infamously Bolivia, private companies raised the price of water so much that poor families couldn't afford enough to meet basic needs.

But more recently emphasis has shifted to privatizing water in richer countries. "These are the countries that can afford to pay," says water rights attorney James Olson. "They've got huge infrastructure needs, shrinking water reserves, and money."

The need for better water management is especially acute in China. As groundwater demands increase in Beijing, wells dug around the city must reach ever-greater depths (nearly two-thirds of a mile or more, according to a recent World Bank report) to hit fresh water. With contracts to supply water becoming more lucrative, the number of private water utilities has skyrocketed. But in order to recover investment costs, companies have dramatically raised the price of water. "It's more than most families can afford to pay," says Ge Yun, an economist with the Xinjiang Conservation Fund. "So as more water goes private, fewer people have access to it."

The World Bank continues to promote privatization, noting that higher water prices are necessary to induce conservation. Public utilities rarely charge enough to reflect the true economic and social costs of water, which privatization advocates argue is the root cause of unsustainable water use. From the perspective of social welfare, even market prices are too low if they fail to account for externalities. But economic efficiency may conflict with the goal of equity. Privatization may work best when combined with policies ensuring that poorest can afford enough water to meet their basic needs, as in the South African system that provides a basic supply of water for free, with increasing prices for larger quantities.

*Source:* Interlandi, 2010.

## 5. THE FUTURE OF WATER

As the human population increases, available freshwater per person will decrease:

[According to projections], more than 2.8 billion people in 48 countries will face water stress or scarcity conditions by 2025. Of these countries, 40 are in West Asia, North Africa or sub-Saharan Africa. Over the next two decades, population increases and growing demands are projected to push all the West Asian countries into water scarcity conditions. By 2050, the number of countries facing water stress or scarcity could rise to 54, with a combined population of four billion people—about 40 percent of the projected global population of 9.4 billion.<sup>61</sup>

Water shortages will be exacerbated in some regions because of climate change. Warmer temperatures speed up the hydrological cycle. In general, already wet areas will become wetter, increasing the likelihood of flooding. But already arid areas are likely to become drier, increasing the probability of droughts.<sup>62</sup> (See Box 8.)

### **Box 8: Hundred-Year Forecast: Drought**

Drought conditions were widespread in the United States in 2012, and the average temperature in the country set a new record high. A severe drought hit the South Central U.S. states in 2011 and an extreme five-year drought took place in Western states in the early 2000s. Until recently many scientists thought of climate change as a threat to “the future.” But with drought conditions occurring with increasing frequency, it is becoming increasingly clear that we may already be living with the “new normal” of climate change.

Still, the worst may be yet to come. Assuming no significant policy changes, projections by the Intergovernmental Panel on Climate Change indicate that *average* rainfall in the American West will be less than the average during the 2000-2004 drought. Climate change models “suggest that what we consider today to be an episode of severe drought might even be classified as a period of abnormal wetness by the end of the century and that a coming mega-drought—a prolonged, multi-decade period of significantly below-average precipitation—is possible and likely in the American West.”

Emergency measures instituted during recent droughts may need to be made permanent. The extent of irrigated agriculture may need to be reduced. While there may still be time to avoid the risk of mega-droughts, “there can be little doubt that what was once thought to be a future threat is suddenly, catastrophically upon us.”

*Source:* Schwalm et al., 2012.

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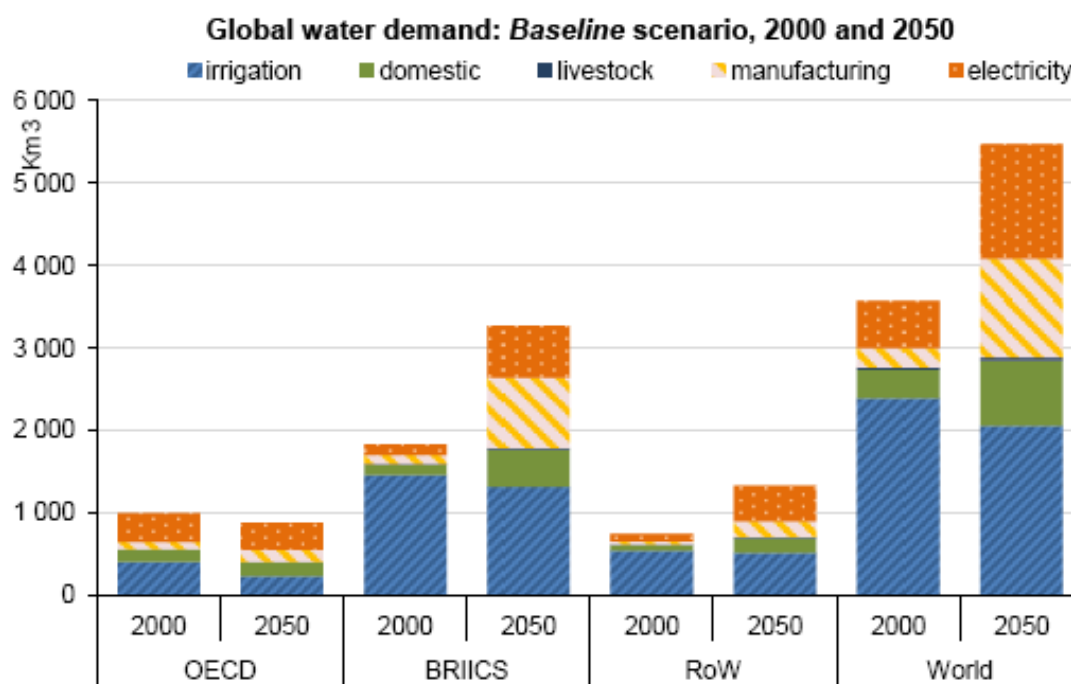
<sup>61</sup> UNEP, 2008.

<sup>62</sup> Dore, 2005.

## Projections for 2050

Global water demand is projected to increase by 55 percent between 2000 and 2050, as shown in Figure 15. All the demand growth is expected to occur in countries that are not members of the Organization for Economic Cooperation and Development (OECD), mainly China and India. While the global demand for irrigation water is actually projected to decline in the coming decades due to increased irrigation efficiency, significant growth is expected for manufacturing, domestic, and electricity needs. According to the OECD, “In the absence of major policy changes and much better water management the situation will deteriorate and water availability will become increasingly uncertain.”<sup>63</sup>

**Figure 15: Global Water Demand, 2000 and 2050**



Note :BRICS = Brazil, Russia, India, Indonesia, China and South Africa; RoW = rest of the world

Source: OECD, 2012.

These projections might be modified with the impacts of climate change, which is feared to exacerbate water scarcities in arid and semi-arid regions. The mega-drought currently experienced by the Western States of the U.S. might become a permanent feature of this region, which could irreversibly turn its ecosystems into parched desert lands. The combination of increasing demand and limited supplies means that water allocation and management will remain crucial issues throughout the twenty-first century.

<sup>63</sup> OECD, 2012, p. 1.



## SUMMARY

Water systems are under pressure from steadily growing agricultural, industrial, and urban demand. Many countries currently experience permanent water stress, defined as less than 1,700 cubic meters per capita available supply. Shortages will become more serious as population grows and climate change impacts precipitation patterns and glacial runoff.

Increasing supply by pumping from aquifers has led to groundwater overdraft in major water-scarce areas throughout the world. Construction of dams also increases available supply, but most major dam sites are already being exploited, and new dam construction often involves major environmental and social costs. Desalination offers the potential to tap into a virtually unlimited supply of ocean water, but it is energy intensive and expensive.

Sources of water include “green”, “blue”, and “gray” water – green in natural ecosystems, blue in bodies of water such as lakes and aquifers, and gray in runoff from human use diluted sufficiently to be available for reuse. The concept of “virtual water” includes all water used in the production of a good, and can be the basis for the calculation of a “water footprint” for an individual or country. The virtual water concept can also be used to measure the amount of water embodied in traded goods, showing virtual water flows between countries.

Proper water pricing can promote conservation and encourage technologies for efficient water use. Government policies, however, often subsidize water, thereby encouraging overuse. Higher prices will reduce demand, but since water demand is inelastic, relatively large price increases are necessary to induce significant conservation. Well-designed price structures, such as increasing block pricing, can also promote conservation.

In theory, water markets can increase the economic efficiency of water allocation by allowing transfers from low-valued uses to higher-valued uses. Water markets can also be used to meet environmental objectives, although the results have been mixed. Privatization of water supplies has also produced mixed results, expanding affordable access in some situations while leading to dramatic price increases and reduced access in other cases. The evidence indicates that while both the private and public sectors have a role to play in meeting water challenges, regulation and institutions are needed to ensure that water is optimally managed.

## DISCUSSION QUESTIONS

1. Suppose you were managing a public water utility facing a shortage due to drought conditions. What steps would you take in response to the drought?
2. Human demands for water can lead to an insufficient supply for maintaining natural resources such as wetlands and fish habitat. How would you balance the allocation of water between human and environmental demands?
3. Do you believe that access to safe drinking water is a fundamental human right? How should water be priced in developing countries, considering the potentially conflicting issues of affordability and conservation?

## GLOSSARY

**absolute water scarcity:** when the water supplies in a given region fall below 500 cubic meters per person per year.

**average-cost pricing:** a water pricing strategy in which price is set equal to the average cost of production (or equal to average cost plus a profit mark-up if the water utility is a for-profit entity).

**beneficial use:** term used to refer to the use of water for productive purposes, such as irrigation or municipal supplies.

**economic water scarcity:** situations where proper infrastructure in water distribution, water recycling and treatment, and sanitation are lacking, leading to inadequate water supply

**desalination:** the removal of salt from ocean water to make it usable for irrigation, industrial, or municipal water supplies.

**hydrologic cycle:** the natural purification of water through evaporation and precipitation.

**micro-irrigation:** irrigation systems that increase the efficiency of water use by applying water in small quantities close to the plants.

**price elasticity of demand:** the responsiveness of the quantity demanded to price, equal to the percentage change in quantity demanded divided by the percentage change in price.

**prior appropriation water rights:** a system of water rights allocation in which rights are not based on land ownership but on established beneficial uses.

**regulated monopolies:** monopolies that are regulated by an external entity, for example through controls on price or profits.

**riparian water rights:** a system of water rights allocation based on adjacent land ownership.

**tragedy of the commons:** an expression used by Garrett Hardin (1968) to describe the perverse effect resulting from the pursuit of personal interest by each individual user of a common resource in the absence of regulation of the access to the resource (in quantity and quality), leading to its degradation and potential destruction.

**virtual water:** is the volume of freshwater used to produce any product, measured at the place where the product was actually produced

**water consumption:** water that is permanently withdrawn and consumed, so that it cannot be returned to the source.

**water footprint:** Is defined for any consumer (individual, institution, Country) as the total volume of freshwater consumed and polluted for the production of the goods and services consumed by the consumer. It is calculated by adding the direct water use by people and their indirect water use (the total amount of all virtual water contained in all consumptions).

**water markets:** mechanism to sell water or water rights to potential buyers. (15)

**water pricing:** setting the price of water to influence the quantity consumed.

**water privatization:** the management of water resources by a private for-profit entity as opposed to a public utility.

**water scarce:** term used for countries where freshwater supplies are less than 1,000 cubic meters per person per year.

**water withdrawal:** water taken from a surface or groundwater source (water withdrawal is distinct from **water consumption**, since water withdrawn may be returned to the source or to another source after use).

**water stressed:** term used for countries where freshwater supplies are between 1,700 and 1,000 cubic meters per person per year.

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## WEBSITES

1. <http://www.epa.gov/gateway/learn/water.html> The U.S. Environmental Protection Agency's water portal, with links to information about watershed protection, oceans, drinking water, and freshwater.
2. <http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/> Website for the United Nations' World Water Development Report, published every three years. Current and past reports can be freely downloaded.
3. <http://www.fao.org/nr/water/> The Food and Agriculture Organization's water portal, with reports and links to a database of water information.
4. [http://waterfootprint.org/media/downloads/Hoekstra\\_and\\_Chapagain\\_2007.pdf](http://waterfootprint.org/media/downloads/Hoekstra_and_Chapagain_2007.pdf) This article explains what a water footprint is and how it is calculated. Data is included for many countries allowing for cross-country analysis of water use and consumption.
5. <http://www.flowthefilm.com/> Irena Salina's award-winning documentary investigation into what experts label the most important political and environmental issue of the 21st Century
6. <http://graphics.latimes.com/food-water-footprint/> This website shows how much water is needed to produce various food items and allows users to calculate the water footprint for a given meal.
7. Sites where you can calculate your own water footprint:  
<http://www.gracelinks.org/1408/water-footprint-calculator> and  
<http://waterfootprint.org/en/resources/interactive-tools/personal-water-footprint-calculator>