Water: The Next Great Technological Frontier

The Technology Investor

archives

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All day I've faced a barren waste
Without the taste of water
Cool water…

> *Cool Water* by Bob Nolan (1936)

When Nolan wrote that song – about a man and his mule in the desert – it's doubtful he knew that he was prefiguring a world to come. Despite the massive abundance of water on our planet (and throughout the known universe, in fact), access to potable water (or a lack thereof) may prove to be the defining social struggle of this century, much like oil in the last. But a plethora of new technologies aim to nip the problem in the bud. Will they be enough?

There Is a *Lot* of Water Out There

Water is not scarce. It is made up of the first and third most common elements in the universe, and the two readily react to form a highly stable compound that maintains its integrity even at temperature extremes.

Hydrologist Dr. Vincent Kotwicki, in his paper *Water in the Universe*, writes:

> "Water appears to be one of the most abundant molecules in the Universe. It dominates the environment of the Earth and is a main constituent of numerous planets, moons and comets. On a far greater scale, it possibly contributes to the so-called 'missing mass' [i.e., dark matter] of the Universe and may initiate the birth of stars inside the giant molecular clouds."

Oxygen has been found in the newly discovered "cooling flows" – heavy rains of gas that appear to be falling into galaxies from the space once thought empty surrounding them, giving rise to yet more water.

How much is out there? No one can even take a guess, since no one knows the composition of the dark matter that makes up as much as 90% of the mass of the universe. If comets, which are mostly ice, are a large constituent of dark matter, then, as Dr. Kotwicki writes, "the remote uncharted (albeit mostly frozen) oceans are truly unimaginably big."

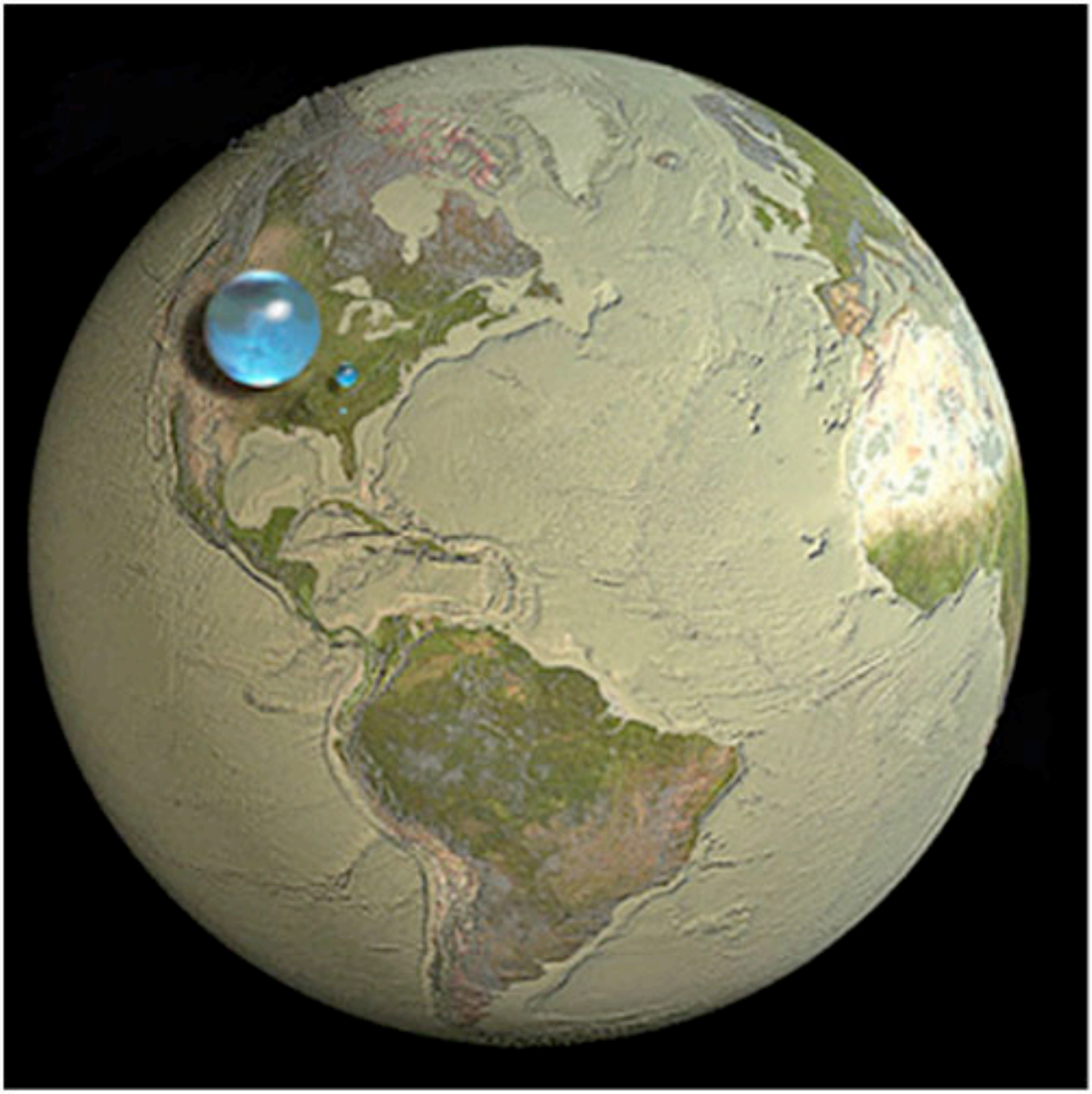
Back home, Earth is often referred to as the "water planet," and it certainly looks that way from space. H_2O covers about 70% of the surface of the globe. It makes all life as we know it possible.

The Blue Planet?

However it got here – theories abound from outgassing of volcanic eruptions to deposits by passing comets and ancient crossed orbits – water is what gives our planet its lovely, unique blue tint, and there appears to be quite a lot of it.

That old axiom that the earth is 75% water... Not quite. In reality, water constitutes only 0.07% of the earth by mass, or 0.4% by volume.

This is how much we have, depicted graphically:



Credit: Howard Perlman, USGS; globe illustration by Jack Cook, Woods Hole Oceanographic Institution (©); Adam Nieman.

What this shows is the relative size of our water supply if it were all gathered together into a ball and superimposed on the globe.

The large blob, centered over the western US, is all water (oceans, icecaps, glaciers, lakes, rivers, groundwater, and water in the atmosphere). It's a sphere about 860 miles in diameter, or roughly the distance from Salt Lake City to Topeka. The smaller sphere, over Kentucky, is the fresh water in the ground and in lakes, rivers, and swamps.

Now examine the image closely. See that last, tiny dot over Georgia? It's the fresh water in lakes and rivers.

Looked at another way, that ball of all the water in the world represents a total volume of about 332.5 million cubic miles. But of this, 321 million mi^3, or 96.5%, is saline – great for fish, but undrinkable without the help of nature or some serious hardware. That still leaves a good bit of fresh water, some 11.6 million mi^3, to play with. Unfortunately, the bulk of that is locked up in icecaps, glaciers, and permanent snow, or is too far underground to be accessible with today's technology. (The numbers come from the USGS; obviously, they are estimates and they change a bit every year, but they are accurate enough for our purposes.)

Accessible groundwater amounts to 5.614 million mi^3, with 55% of that saline, leaving a little over 2.5 million mi^3 of fresh groundwater. That translates to about 2.7 exa-gallons of fresh water, or about 2.7 billion billion gallons (yes billions of billions, or 10^{18} in scientific notation), which is about a third of a billion gallons of water per person. Enough to take a long shower every day for many lifetimes...

However, not all of that groundwater is easily or cheaply accessible. The truth is that the surface is the source for the vast majority – nearly 80% – of our water. Of surface waters, lakes hold 42,320 mi^3, only a bit over half of which is fresh, and the world's rivers hold only 509 mi^3 of fresh water, **less than 2/10,000 of 1% of the planetary total**.

And that's where the problem lies. In 2005 in the US alone, we humans used about 328 billion gallons of surface water **per day**, compared to about 83 billion gallons per day of water from the ground. Most of that surface water, by far, comes from rivers. Among these, one of the most important is the mighty Colorado.

Horseshoe Bend, in Page, AZ. (AP Photo)

Tapping Ol' Man River

Or perhaps we should say "the river formerly known as the mighty Colorado." That old Colorado – the one celebrated in centuries of American Western song and folklore; the one that exposed two billion years of geologic history in the awesome Grand Canyon – is gone. In its place is… well, Las Vegas – the world's gaudiest monument to hubristic human overreach, and a big neon sign advertising the predicament now faced by much of the world.

It's well to remember that most of the US west of the Mississippi ranges from relatively dry to very arid, to desert, to lifeless near-moonscapes. The number of people that could be supported by the land, especially in the Southwest, was always small and concentrated along the riverbanks. Tribal clusters died out with some regularity. And that's the way it would have remained, except for a bit of ingenuity that suddenly loosed two powerful forces on the area: electrical power, and an abundance of water that seemed as limitless as the sky.

In September of 1935, President Roosevelt dedicated the pinnacle of engineering technology up to that point: Hoover Dam. The dam did two things. It served as a massive hydroelectric generating plant, and it backed up the Colorado River behind it, creating Lake Mead, the largest reservoir in the country.

Early visitors dubbed Hoover Dam the "Eighth Wonder of the World," and it's easy to see why. It was built on a scale unlike anything before it. It's 725 feet high and contains 6 million tons of concrete, which would pave a road from New York to Los Angeles. Its 19 generators produce 2,080 MW of electricity, enough to power 1.75 million average homes.

The artificially created Lake Mead is 112 miles long, with a maximum depth of 590 feet. It has a surface area of 250 square miles and an active capacity of 16 million acre-feet.

Hoover Dam was intended to generate sufficient power and impound an ample amount of water, to meet any conceivable need. But as things turned out, grand as the dam is, it wasn't conceived grandly enough... because it is 35 miles from Las Vegas, Nevada.

Vegas had a permanent population in 1935 of 8,400, a number that swelled to 25,000 during the dam construction as workers raced in to take jobs that were scarce in the early Depression years. Those workers, primarily single men, needed something to do with their spare time, so the Nevada state legislature legalized gambling in 1931. Modern Vegas was born.

The rise of Vegas is well chronicled, from a middle-of-nowhere town to the largest city founded in the 20th century and the fastest-growing in the nation – up until the 2008 housing bust. Somehow, those 8,400 souls turned into a present population of over 2 million that exists all but entirely to service the 40 million tourists who visit annually. And all this is happening in a desert that sees an average of 10 days of measurable rainfall per year, totaling about 4 inches.

In order to run all those lights, fountains, and revolving stages, Las Vegas requires 5,600 MW of electricity on a summer day. Did you notice that that's more than 2.5 times what the giant

Hoover Dam can put out? Not to mention that those 42 million people need a lot of water to drink to stay properly hydrated in the 100+ degree heat. And it all comes from Lake Mead.

So what do you think is happening to the lake?

If your guess was, "it's shrinking," you're right. The combination of recent drought years in the West and rapidly escalating demand has been a dire double-whammy, reducing the lake to 40% full. Normally, the elevation of Lake Mead is 1,219 feet. Today, it's at 1,086 feet and dropping by ten feet a year (and accelerating). That's how much more water is being taken out than is being replenished.

This is science at its simplest. If your extraction of a renewable resource exceeds its ability to recharge itself, it will disappear – end of story. In the case of Lake Mead, that means going dry, an eventuality to which hydrologists assign a 50% probability in the next twelve years. That's by 2025.

Nevadans are not unaware of this. There is at the moment a frantic push to get approval for a massive pipeline project designed to bring in water from the more favored northern part of the state. Yet even if the pipeline were completed in time, and there is stiff opposition to it (and you thought only oil pipelines gave way to politics and protests), that would only resolve one issue. There's another. A big one.

Way before people run out of drinking water, something else happens: When Lake Mead falls below 1,050 feet, the Hoover Dam's turbines shut down – less than four years from now, if the current trend holds – and in Vegas the lights start going out.

What Doesn't Stay in Vegas

Ominously, these water woes are not confined to Las Vegas. Under contracts signed by President Obama in December 2011, Nevada gets only 23.37% of the electricity generated by the Hoover Dam. The other top recipients: Metropolitan Water District of Southern California (28.53%); state of Arizona (18.95%); city of Los Angeles (15.42%); and Southern California Edison (5.54%).

You can always build more power plants, but you can't build more rivers, and the mighty Colorado carries the lifeblood of the Southwest. It services the water needs of an area the size of France, in which live 40 million people. In its natural state, the river poured 15.7 million acre-feet of water into the Gulf of California each year. Today, twelve years of drought have reduced the flow to about 12 million acre-feet, and human demand siphons off every bit of it; at its mouth, the riverbed is nothing but dust.

Nor is the decline in the water supply important only to the citizens of Las Vegas, Phoenix, and Los Angeles. It's critical to the whole country. The Colorado is the sole source of water for southeastern California's Imperial Valley, which has been made into one of the most productive agricultural areas in the US despite receiving an average of three inches of rain per year.

The Valley is fed by an intricate system consisting of 1,400 miles of canals and 1,100 miles of pipeline. They are the only reason a bone-dry desert can look like this:

Intense conflicts over water will probably not be confined to the developing world. So far, Arizona, California, Nevada, New Mexico, and Colorado have been able to make and keep agreements defining who gets how much of the Colorado River's water. But if populations continue to grow while the snowcap recedes, it's likely that the first shots will be fired before long, in US courtrooms. If legal remedies fail… a war between Phoenix and LA might seem far-fetched, but at the minimum some serious upheaval will eventually ensue unless an alternative is found quickly.

A Litany of Crises

Water scarcity is, of course, not just a domestic issue. It is far more critical in other parts of the world than in the US. It will decide the fate of people and of nations.

Worldwide, we are using potable water way faster than it can be replaced. Just a few examples:

- The Aral Sea was once the fourth-largest freshwater lake in the world; today, it has shrunk to 10% of its former size and is on track to disappear entirely by 2020. Watching what has happened just since the turn of the century is stunning.
- The legendary Jordan River is flowing at only 2% of its historic rate.
- In Africa, desertification is proceeding at an alarming rate. Much of the northern part of the continent is already desert, of course. But beyond that, a US Department of Agriculture study places about 2.5 million km^2 of African land at low risk of desertification, 3.6 million km^2 at moderate risk, 4.6 million km^2 at high risk, and 2.9 million km^2 at very high risk. "The region that has the highest propensity," the report says, "is located along the desert margins and occupies about 5% of the land mass. It is estimated that about 22 million people (2.9% of the total population) live in this area."
- A 2009 study published in the American Meteorological Society's *Journal of Climate* analyzed 925 major rivers from 1948 to 2004 and found an overall decline in total discharge. The reduction in inflow to the Pacific Ocean alone was about equal to shutting off the Mississippi River. The list of rivers that serve large human populations and experienced a significant decline in flow includes the Amazon, Congo, Chang Jiang (Yangtze), Mekong, Ganges, Irrawaddy, Amur, Mackenzie, Xijiang, Columbia, and Niger.

Supply is not the only issue. There's also potability. Right now, 40% of the global population has little to no access to clean water, and despite somewhat tepid modernization efforts, that figure is actually expected to jump to 50% by 2025. When there's no clean water, people will drink dirty water – water contaminated with human and animal waste. And that breeds illness. It's estimated that fully half of the world's hospital beds today are occupied by people with water-borne diseases.

Food production is also a major contributor to water pollution. To take two examples:

- The "green revolution" has proven to have an almost magical ability to provide food for an ever-increasing global population, but at a cost. Industrial cultivation is extremely water intensive, with 80% of most US states' water usage going to agriculture – and in some, it's as high as 90%. In addition, factory farming uses copious amounts of fertilizer, herbicides, and pesticides, creating serious problems for the water supply because of toxic runoff.
- Modern livestock facilities – known as concentrated animal feeding operations (CAFOs) – create enormous quantities of animal waste that is pumped into holding ponds. From there, some of it inevitably seeps into the groundwater, and the rest eventually has to be dumped somewhere. Safe disposal practices are often not followed, and regulatory oversight is lax. As a result, adjacent communities' drinking water can come to contain dangerously high levels of *E. coli* bacteria and other harmful organisms.

Not long ago, scientists discovered a whole new category of pollutants that no one had previously thought to test for: drugs. We are a nation of pill poppers and needle freaks, and the drugs we introduce into our bodies are only partially absorbed. The remainder is excreted and finds its way into the water supply. Samples recently taken from Lake Mead revealed detectable levels of birth control medication, steroids, and narcotics... which people and wildlife are drinking.

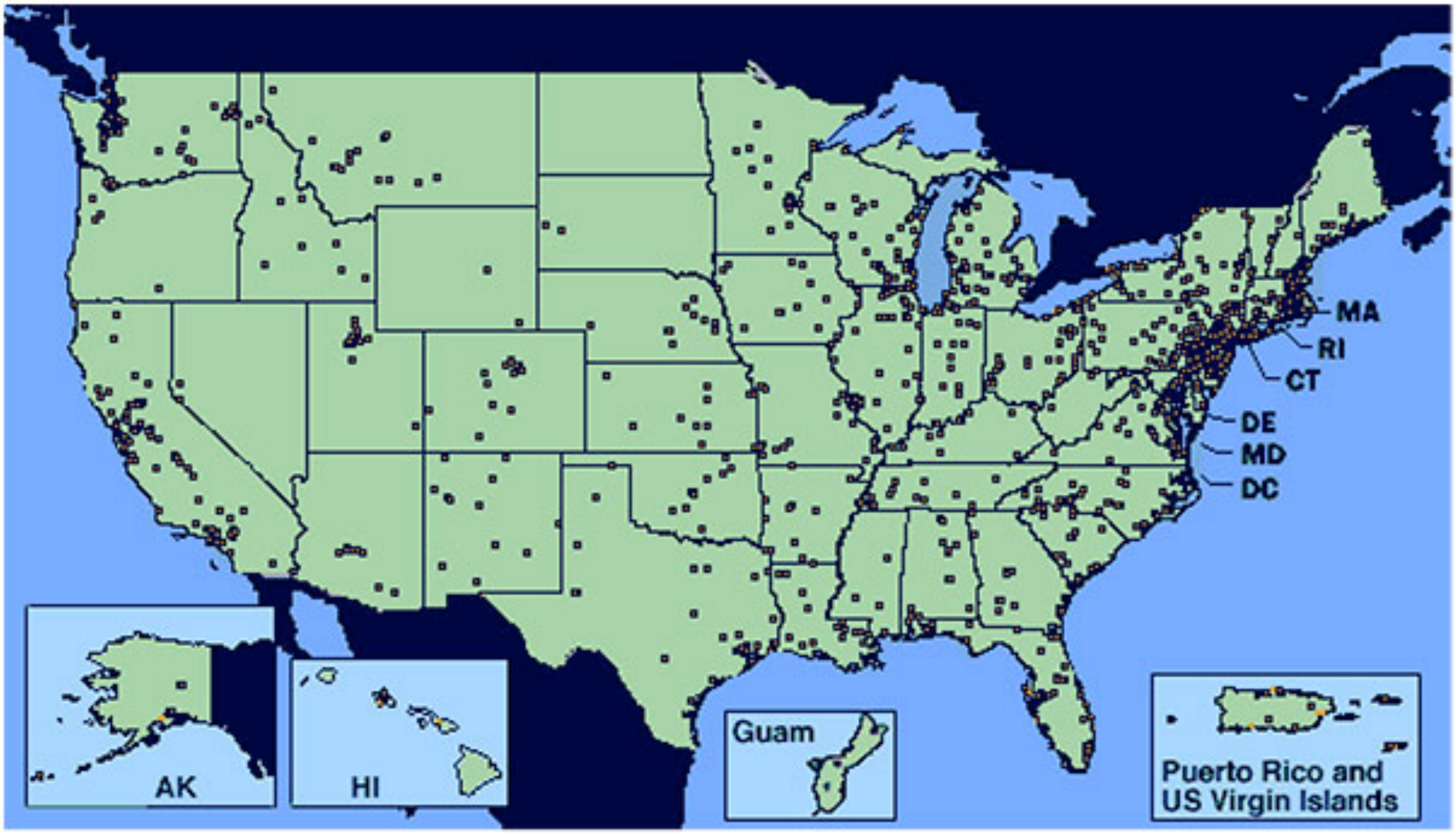
Most lethal of all are industrial pollutants that continue to find their way into the water supply. The carcinogenic effects of these compounds have been well documented, as the movie-famed Erin Brockovich did with hexavalent chromium.

But the problem didn't go away with Brockovich's court victory. The sad fact is that little has changed for the better. In the US, our feeble attempt to deal with these threats was the passage in 1980 of the so-called Superfund Act. That law gave the federal government – and specifically the Environmental Protection Agency (EPA) – the authority to respond to chemical emergencies and to clean up uncontrolled or abandoned hazardous-waste sites on both private and public lands. And it supposedly provided money to do so.

How's that worked out? According to the Government Accountability Office (GAO), "After decades of spearheading restoration efforts in areas such as the Great Lakes and the Chesapeake Bay, improvements in these water bodies remain elusive … EPA continues to face the challenges posed by an aging wastewater infrastructure that results in billions of gallons of untreated sewage entering our nation's water bodies … Lack of rapid water-testing methods and development of current water quality standards continue to be issues that EPA needs to address."

Translation: the EPA hasn't produced. How much of this is due to the typical drag of a government bureaucracy and how much to lack of funding is debatable. Whether there might be a better way to attack the problem is debatable. But what is not debatable is the magnitude of the problem stacking up, mostly unaddressed.

Just consider that the EPA has a backlog of 1,305 highly toxic Superfund cleanup sites on its to-do list, in every state in the union (except apparently North Dakota, in case you want to try to escape – though the proliferation of hydraulic fracking in that area may quickly change the map, according to some of its detractors – it's a hotly debated assertion).



About 11 million people in the US, including 3-4 million children, live within one mile of a federal Superfund site. The health of all of them is at immediate risk, as is that of those living directly downstream.

We could go on about this for page after page. The situation is depressing, no question. And even more so is the fact that there's little we can do about it. There is no technological quick fix.

Peak oil we can handle. We find new sources, we develop alternatives, and/or prices rise. It's all but certain that by the time we actually run out of oil, we'll already have shifted to something else.

But "peak water" is a different story. There are no new sources; what we have is what we have. Absent a profound climate change that turns the evaporation/rainfall hydrologic cycle much more to our advantage, there likely isn't going to be enough to around.

As the biosphere continually adds more billions of humans (the UN projects there will be another 3.5 billion people on the planet, a greater than 50% increase, by 2050 before a natural plateau really starts to dampen growth), the demand for clean water has the potential to far outstrip dwindling supplies. If that comes to pass, the result will be catastrophic. People around the world are already suffering and dying *en masse* from lack of access to something drinkable... and the problems look poised to get worse long before they get better.

Searching for a Way Out

With a problem of this magnitude, there is no such thing as a comprehensive solution. Instead, it will have to be addressed by chipping away at the problem in a number of ways, which the world is starting to do.

With much water not located near population centers, transportation will have to be a major part of the solution. With oil, a complex system of pipelines, tankers, and trucking fleets has been erected, because it's been profitable to do so. The commodity has a high intrinsic value. Water doesn't – or at least hasn't in most of the modern era's developed economies – and thus delivery has been left almost entirely to gravity. Further, the construction of pipelines for water that doesn't flow naturally means taking a vital resource from someone and giving it to someone else, a highly charged political and social issue that's been known to lead to protest and even violence. But until we've piped all the snow down from Alaska to California, transportation will be high on the list of potential near term solutions, especially to individual supply crunches, just as it has been with energy.

Conservation measures may help too, at least in the developed world, though the typical lawn-watering restrictions will hardly make a dent. Real conservation will have to come from curtailing industrial uses like farming and fracking.

But these bandage solutions can only forestall the inevitable without other advances to address the problems. Thankfully, where there is a challenge, there are always technology innovators to help address it. It was wells and aqueducts that let civilization move from the riverbank inland, irrigation that made communal farming scale, and sewers and pipes that turned villages into cities, after all. And just as with the dawn of industrial water, entrepreneurs are developing some promising tech developments, too.

Given how much water we use today, there's little doubt that conservation's sibling, recycling, is going to be big. Microfiltration systems are very sophisticated and can produce recycled water that is near-distilled in quality. Large-scale production remains a challenge, as is the reluctance of people to drink something that was reclaimed from human waste or industrial runoff. But that might just require the right spokesperson. California believes so, in any case, as it forges ahead with its Porcelain Springs initiative. A company called APTwater has taken on the important task of purifying contaminated leachate water from landfills that would otherwise pollute the groundwater. This is simply using technology to accelerate the natural process of replenishment by using energy, but if it can be done at scale, we will eventually reach the point where trading oil or coal for clean drinking water makes economic sense. It's already starting to in many places.

Inventor Dean Kamen of Segway fame has created the Slingshot, a water-purification machine that could be a lifesaver for small villages in more remote areas. The size of a dorm-room refrigerator, it can produce 250 gallons of water a day, using the same amount of energy it takes to run a hair dryer, provided by an engine that can burn just about anything (it's been run on cow dung). The Slingshot is designed to be maintenance-free for at least five years.

Kamen says you can "stick the intake hose into anything wet – arsenic-laden water, salt water, the latrine, the holding tanks of a chemical waste treatment plant; really, anything wet – and the outflow is one hundred percent pure pharmaceutical-grade injectable water."

That naturally presupposes there is something wet to tap into. But Coca-Cola, for one, is a believer. This September, Coke entered into a partnership with Kamen's company, Deka Research, to distribute Slingshots in Africa and Latin America.

Ceramic filters are another, low-tech option for rural areas. Though clean water output is very modest, they're better than nothing. The ability to decontaminate stormwater runoff would be a boon for cities, and AbTech Industries is producing a product to do just that.

In really arid areas, the only water present may be what's held in the air. Is it possible to tap that source? "Yes," say a couple of cutting-edge tech startups. Eole Water proposes to extract atmospheric moisture using a wind turbine. Another company, NBD Nano, has come up with a self-filling water bottle that mimics the Namib Desert beetle. Whether the technology is scalable to any significant degree remains to be seen.

And finally, what about seawater? There's an abundance of that. If you ask a random sampling of folks in the street what we're going to do about water shortages on a larger scale, most of them will answer, "desalination." No problem. Well, yes problem.

Desalination (sometimes shortened to "desal") plants are already widespread, and their output is ramping up rapidly. According to the International Desalination Association, in 2009 there were 14,451 desalination plants operating worldwide, producing about 60 million cubic meters of water per day. That figure rose to 68 million m^3/day in 2010 and is expected to double to 120 million m^3/day by 2020. That sounds impressive, but the stark reality is that it amounts to only around a quarter of one percent of global water consumption.

Boiling seawater and collecting the condensate has been practiced by sailors for nearly two millennia. The same basic principle is employed today, although it has been refined into a procedure called "multistage flash distillation," in which the boiling is done at less than atmospheric pressure, thereby saving energy. This process accounts for 85% of all desalination worldwide. The remainder comes from "reverse osmosis," which uses semipermeable membranes and pressure to separate salts from water.

The primary drawbacks to desal are that a plant obviously has to be located near the sea, and that it is an expensive, highly energy-intensive process. That's why you find so many desal facilities where energy is cheap, in the oil-rich, water-poor nations of the Middle East. Making it work in California will be much more difficult without drastically raising the price of water. And Nevada? Out of luck. Improvements in the technology are bringing costs of production down, but the need for energy, and lots of it, isn't going away. By way of illustration, suppose the US would like to satisfy half of its water needs through desalination. All other factors aside, meeting that goal would require the construction of more than 100 new electric power plants, each dedicated solely to that purpose, and each with a **gigawatt** of capacity.

Moving desalinated water from the ocean inland adds to the expense. The farther you have to transport it and the greater the elevation change, the less feasible it becomes. That makes desalination impractical for much of the world. Nevertheless, the biggest population centers tend to be clustered along coastlines, and demand is likely to drive water prices higher over time, making desal more cost-competitive. So it's a cinch that the procedure will play a steadily increasing role in supplying the world's coastal cities with water.

In other related developments, a small tech startup called NanOasis is working on a desalination process that employs carbon nanotubes. An innovative new project in Australia is demonstrating that food can be grown in the most arid of areas, with low energy input, using solar-desalinated seawater. It holds the promise of being very scalable at moderate cost.

The Future

This article barely scratches the surface of a very broad topic that has profound implications for the whole of humanity going forward. The World Bank's Ismail Serageldin puts it succinctly: "The wars of the 21st century will be fought over water."

There's no doubt that this is a looming crisis we cannot avoid. Everyone has an interest in water. How quickly we respond to the challenges ahead is going to be a matter, literally, of life and death. Where we have choices at all, we had better make some good ones.

From an investment perspective, there are few ways at present to acquire shares in the companies that are doing research and development in the field. But you can expect that to change as technologies from some of these startups begin to hit the market, and as the economics of water begin to shift in response to the changing global landscape.

We'll be keeping an eye out for the investment opportunities that are sure to be on the way.