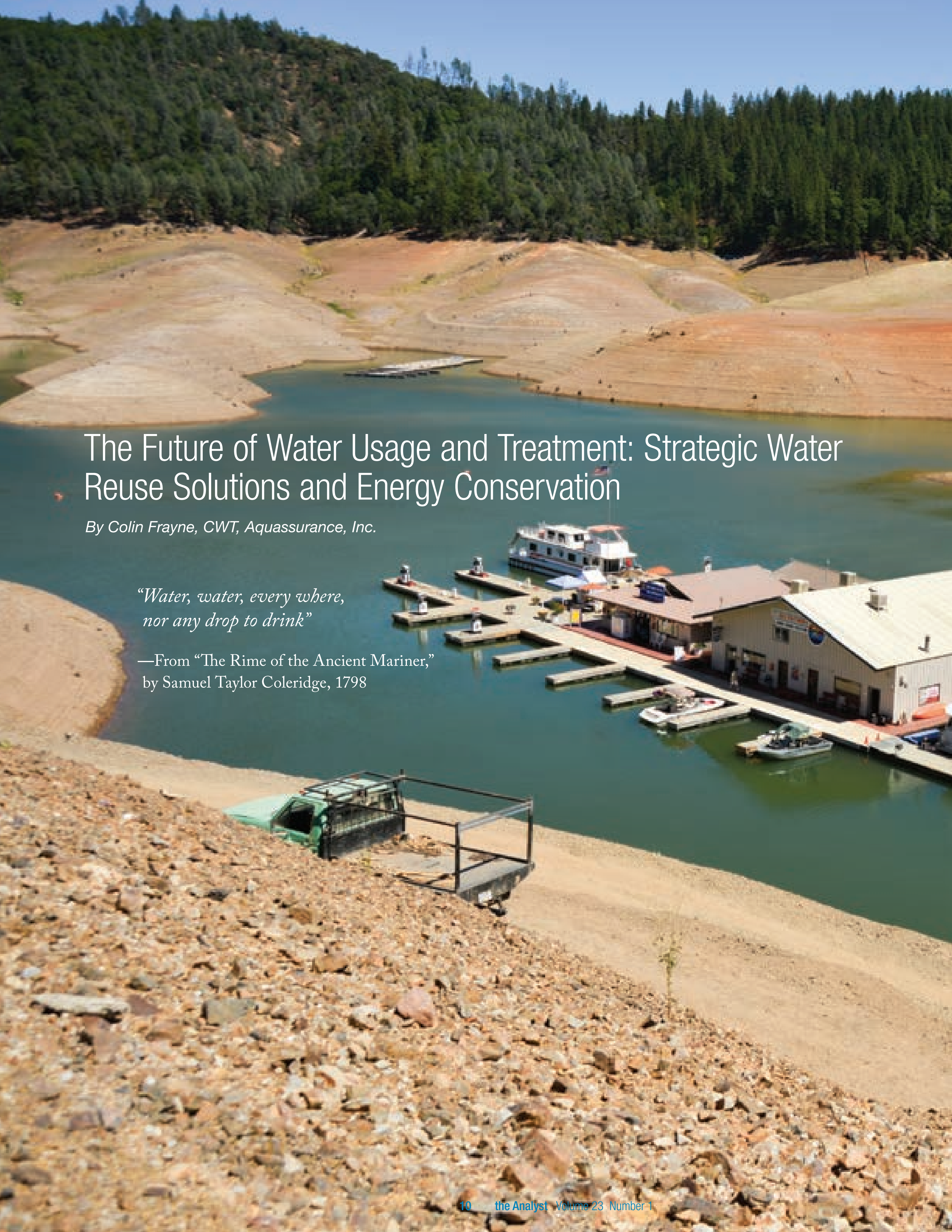

The Future of Water Usage and Treatment: Strategic Water Reuse Solutions and Energy Conservation

By Colin Frayne, CWT, Aquassurance, Inc.

"Water, water, every where,
nor any drop to drink"

—From "The Rime of the Ancient Mariner," by Samuel Taylor Coleridge, 1798

Lake Shasta, USA - August 17, 2014: California's lingering drought exposes the 180-200 foot drop in water levels. The state's largest reservoir is receding at an average of 4.9 inches per day. The 3-year-long drought is affecting tourism and boating recreation.—*photo by David Greitzer*

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Water: the current global position

It is well known that the world faces finite freshwater supplies! We also know that freshwater withdrawals have tripled over the last 50 years and that the world's population is growing by roughly 80 million people each year. Additionally, changes in lifestyles and eating habits are requiring more water. By this I refer, for example, to the many hundreds of millions of newly created middle-class people in developing countries such as China and India who are eating considerably more meat products than ever before, leading cattle, sheep, and pig farms to require more resources in the form of watered pastureland.

Global consumption per capita is increasing, and it is expected that food demands will increase by 50% by 2030. Furthermore, energy demands are also accelerating, with corresponding implications for additional demands on water for steam generation and turbine condenser cooling. Thus, energy demands will likely increase by 60% by 2030. Unfortunately, a byproduct of growth is pollution, especially air and water pollution, and pollution knows no borders! Despite phenomenal growth in certain parts of the world, it remains a fact that 90% of wastewater in developing countries is untreated. We now realize that wastewater treatment and its reuse for a variety of purposes, including drinking water (i.e., "toilet-to-tap"—a "yuck factor" phrase employed by activists in the 1990s to beat back efforts to develop water reuse in Los Angeles and San Diego), is a critical issue for the world. In fact, Singapore has been mixing recycled treated water into its drinking water mains for many years to reduce its imports of potable water from Malaysia.

The current position in the United States and a comparison with some other countries

The United States is the biggest user of water per capita in the world and historically U.S. water tariffs have only been approximately 40% those of European countries such as Germany. This encourages wastefulness and, as a result, U.S. water usage is typically three times as much per capita as other advanced economies. Thus, despite the Great Lakes and all the freshwater they contain, overall, the U.S. supply-demand balance is teetering!

We need solutions to counter water scarcity and provide for sustainability and security just as much as most other countries.

The reason the United States is the world's largest water user per person is in part due to its vast agricultural and industrial output. Note that GDP is directly correlated with total water consumption. So, we must also compare total gallons used by countries; on this matrix, China and India, with their enormous populations, are the truly big consumers on this planet! And these geographic areas are "water troubled." So, China and India jump out as problem countries. Also, Mexico. Most of India and substantial portions of China are already stressed, and China already engages in multi-tiered pricing to discourage unnecessary use of potable water for lesser industrial needs. Many county and city agencies in California and Texas are now also beginning to engage in multi-tiered pricing, and are also returning to the idea of drinking recycled water, or—to placate the squeamish among us—of using the treated water to replenish aquifers (i.e., Ground Water Replenishment System, GRWS). The Orange County Water District and Orange County Sanitation District GRWS, for example, has been successful in its water recycling efforts, but for much of the world, water is a political tool and is priced too cheaply, encouraging waste and inhibiting sustainability. Correctly priced water conserves water and reduces associated energy costs.

Thus, globally, we should expect to see more seawater desalination (with continuous improvements expected with energy recovery systems and membrane types) and greatly increased numbers of industrial and agricultural water reuse projects. Also, we should expect to see realistic and multi-tiered pricing to discourage waste of water and energy! In fact, we are now beginning to see this in the United States, as California recently imposed its first mandatory water restrictions to deal with a prolonged drought and overuse of water. In April of this year (2015), Governor Jerry Brown ordered mandatory water use reductions for the first time in California's history, saying that the state's four-year drought had reached near-crisis proportions after a winter of record-low snowfalls. He directed the state water resources control board to impose a 25 percent reduction on the state's 400 local water supply agencies—which serve 90 percent of California residents—over the coming year.

However 80% of California's water is used for irrigation, and most areas were thought to be exempt due to a complex system of water rights; but we now see this status quo beginning to change, and whether voluntarily or not, farmers are working even harder to find ways to further improve irrigation methods so as to cut down on total water withdrawals and usage!

Water problems, however, are not restricted just to California, Texas, and Atlanta, as the country as a whole needs to spend at least $600 billion now on renewing and expanding its water supply infrastructure. Typically, most major U.S. cities experience water distribution leaks of 14–17%, and in some locations this can reach in excess of 30%. It has been estimated that about 6 billion gallons of water per day, or 2.1 trillion gallons/year, may be wasted in the United States due to leaks.

Limitations on water affects the way AWT member companies now conduct business

How does this global water-use limitation that has been developing for years affect AWT member companies and water technologists? What are the various market sectors using water, and are industrial and commercial customers accepting and adopting the necessary changes? What are our respective parts in the water treatment/water saving process? Also, how good are we—both the customer and the water technologist—at working together to use less water and use it more efficiently, and to wisely reclaim and reuse water? What changes are taking place in the market today, and what is the future for industrial/commercial/institutional water treatment?

First, it is important to know that many different market sectors for water treatment and water systems management exist—each of which has its own specific technical and operational requirements, and thus, limitation or opportunities for water savings and reuse. AWT member companies may work in several market sectors, including the following:

1. Municipal, community, or privately operated potable and wastewater treatment works (POTW), where water purification processes may include various types of filtration, aerobic/anaerobic digestion, and use of coagulants and flocculant chemistries. Also, clarification, micro/ultra filtration (including use of membrane bioreactors [MBR]), reverse osmosis (including seawater RO), clean-in-place (CIP), disinfection, sludge dewatering, and sludge/solids handling. In this market sector it is common practice to recycle filter backwash water (which may be 5-7% of total water flow), and sometimes thickener supernatant and/or liquids from dewatering processes. However, recycled water is subject to additional treatment processes, such as sedimentation, equalization, and/or disinfection, to ensure public health protection, particularly from microbial contaminants such as cryptosporidium, giardia, or minerals such as aluminum, iron, and manganese salts, under the EPA Filter Backwash Recycling Rule (FBRR).

2. Large and basic industries such as steel, oil & gas, sugar, utilities, petrochemical, pulp & paper, mining, metals and hydrocarbon refining, ethanol and bio-fuels, other energy sources. Also, coal washing, flue gas desulfurization, ash ponds, nuclear, chemicals, offshore rigs, and a hundred other water treatment projects. In most or all of these industries, water is also treated and used in high-pressure steam generators, various types of cooling, closed loop, and chilled water systems. Also, treatment is needed for potable water, wastewater, and a multitude of manufacturing areas where water is used as a process fluid. Most large industries also operate wastewater plants. Every manufacturing plant has opportunities for water minimization and reuse, even if the easy solutions for "overhanging fruit' have already been provided. The main requirements prior to reuse are to remove fats, oils, and greases (FOG); reduce biochemical oxygen demand (BOD); and reduce other high-concentration contaminants such as chlorides, heavy metals, and suspended solids. Increasingly, industries are moving to decentralize wastewater treatment plants, as high volumes of low contamination water can be made suitable for reuse after filtration and disinfection, but can also be made unusable by a small volume of highly contaminated water. Dilution is not the solution to pollution!

3. There is a highly specialized and diverse technologies market sector where AWT members may be engaged in providing products and services for a wide range of water treatment applications. Examples include treating water-cooled medical equipment, contaminated groundwater, enhanced oil and shale-gas formation water, water for injection, and drip irrigation for agriculture and horticulture, as well

as aquaculture and high-tech metals and plastics industries. AWT companies may be involved in water use reduction, water cleanup and recovery or reuse schemes, or even zero liquid discharge (ZLD) projects using combinations of evaporation ponds, brine concentrators, falling film evaporators, and crystallizers. Also, many oil and gas fracking drill rigs now do not send their high volumes of severely contaminated produced water somewhere over the state line for reinjection into an old mine shaft, but rather engage in water treatment and reuse programs, employing mobile precipitators, clarifiers, and filter plant systems. Smart solutions are always welcomed.

4. The traditional "middle market" sector covers HVAC condenser cooling, chilled water boiler plant, and potable secondary disinfection for commercial buildings, malls, hospitals, clinics, institutions, schools and colleges, and public buildings, in addition to the automotive industry, printing, light-engineering, data centers, plastics extrusion, white goods, wood products, consumer durables and many other general industries, Also covered are edible oils, wineries, fruit and vegetable washing, flume transport, CIP, sanitation, cannery treatments, and conveyor chain lubricants for the food industry. Yet more middle markets are cleaning and wash-down for meat and poultry and pasteurization for beer and dairy. In every one of these middle market accounts, there is no logical reason why cooling towers have to use potable-grade city water. Some AWT member companies can design and offer customized water recovery systems (such as rainwater harvesting, stormwater collection, and contaminated groundwater recovery and treatment schemes), thus providing a water source that does not come out of the city water tap.

5. How pure is "pure water"? There is an ultrapure water market that requires custom water treatment equipment such as UF, RO, EDI, twin, mixed bed, and (non-site regenerable) service deionization equipment, as well as condensate polishers, filtration, super oxidation, and UV disinfection equipment and services. Ultrapure is the province of data center humidification systems, utility power, the electronics industry, big pharma, healthcare dialysis programs, university research laboratories, and many other industries. Chemicals are also used during the ultrapure water generation process and for CIP. AWT companies can advise on such questions as how to minimize backwash water usage; options for reducing concentrate reject water in RO plants; the suitability of forward osmosis; and best practice for disinfection, storage, and management of ultrapure water.

6. For the residential, strip mall, and other light commercial market sector, there is point-of-entry and point-of-use (POE/POU) equipment, plus dozens of filter types, softeners, pumps, specialist contaminant removal, resins, media, and other consumables. Now there is a variety of site-generated oxidizing biocide equipment being used, not only in this market sector, but also in bigger middle market and industrial market sectors. Generators are available for mixed oxides, chlorine dioxide, ozone, hydrogen peroxide, peroxyacetic acid, etc. and can be very useful for disinfecting various reclaimed/recycled waters.

It can be seen that there is a very wide range of commercial and institutional buildings, power generators, and manufacturing enterprises that require water every day in order to operate—lots of water! But the commercial/institutional market sector now uses significantly less water than a dozen years ago. It has seen many changes in those years, one of which is the development of "green buildings" through the U.S. Green Building Council (USGBC) and their Leadership in Energy and Environmental Design (LEED®) Green Building certification program. This program has led to sustainable building site development, energy efficiency, improved materials and resources selection, improved indoor environmental quality, and importantly, credits for a range of water savings. California Title 24 2014 (Building Energy Efficiency Standards), Section 110.2 now mandates that building owners document the maximum cycles of concentration of cooling towers with a local water supply, based on a mechanical compliance form, reviewed and signed by a PE of Record.

Regarding manufacturing industries and their increased focus on saving water and associated energy, many regional water treatment chemical service companies are having to change the way they do business, as customers increasingly look to them to provide additional technical support and a range of water-in to water-out services. This includes working with secondary water sources, operating cooling towers at higher cycles, installing more pre-treatment and water purification equipment, placing less reliance on chemistries, and ensuring less water is discharged to sanitary sewer. These changes have meant closer monitoring, more real-time data collection, and improved operational communications. Now, some AWT firms have become providers of a much wider range of mixed equipment/chemical-based treatment solutions and can treat a greater diversity of lower-grade waters. They are now total water solution providers rather than merely water treatment chemical service firms!

Additionally, for those AWT companies working with industrial process waters and their final discharge to sewer or stream, there are far fewer OEM manufacturers of coagulants and flocculants today due to marketplace mergers and acquisitions, so service companies are having to develop their own specialized blends to meet customer demands for improved coagulation rates, and increased BOD removal rates from wastewater associated with materials such as food and beverages, blood, meat and poultry, textiles, and dyes and inks. Also, customers want faster dewatering of settling sewage sludge, improved filterability and quicker influent/effluent clarification, reduced volumes of backwash and CIP water, and recovery of the spent backwash and CIP solutions. The demand from customers is for less process water to be used (so less water in from the city or well), faster treatment times, and cleaner water on final discharge (so lower discharge costs)—or possibly no discharge. But the water treatment services industry has always been good at working with their customers to find ways to save process water and energy. For example:

- They promote higher cycles in cooling systems to save water and chemicals.
- They use HP boiler blowdown as makeup to cooling towers.
- In dairies, they recover condensate of whey (COW water) for use as boiler makeup.
- In tomato paste plants, they recover evaporated water for reuse in boiler/cooling.

Water usage and savings by one of the biggest water users—the power industry

In 2014 the United States generated about 4.1 billion kilowatt-hours (kwh) of electricity, of which about 67% was from fossil fuels. The average water consumption for U.S. power plants using fossil fuels with cooling towers uses approximately 25 gal/kwh electricity. However, once-through cooling typically requires 37.7 gal/kwh, whereas recirculating cooling water needs only 1.2 gal/kwh (but overall power-plant efficiency is reduced by 2–3% compared to once-through). Thus, these numbers reflect the fact that most power plants use very high volumes of once-through water from lakes and rivers, estuaries, or the sea, rather than saving water by recirculating it over a tower. (Although to be fair, many large pulp and paper mills; chemical, iron, steel, and aluminum plants; and petroleum refineries also use once-through cooling).

So how do we rate the utility power plants for water reuse and energy conservation? In fact, for many years the U.S. fossil fuel power generation industry has recycled low-grade waters to achieve cost and other objectives. Also, the industry has developed combined-cycle power plants, which has significantly improved energy efficiency in electricity generation. Power plants have reduced freshwater needs and recovered potentially lost energy present in exhaust gas streams by using heat-recovery steam generators (HRSC). In some regions of the country, wet-surface air coolers (WSAC), indirect and direct dry-cooling, and even air-cooled steam condensers (which save water but have an additional energy consumption penalty) are used. But there is still a lot more that can be done to save water. As an example, decades ago, South Africa—a country with vast open and arid plains (the highveld) has reduced its freshwater demands for fossil fuel power plants by using indirect and direct dry-cooling systems. Also, they have treated and recycled polluted mine waters and practiced zero liquid discharge (ZLD)! For example:

- Matimba – the largest direct dry-cooled power plant in the world uses only 0.026 gal/kwh.
- Kendal – the largest indirect dry-cooled power plant uses only 0.021 gal/kwh.

And, with some power plants using ZLD, the average water consumption for power plant wet cooling in South Africa is reduced to only 0.5 gal/kwh, which is just 2% of the average for the United States! Perhaps there are some lessons to be learned here by the U.S. power industry? I suspect that in the near future, more and more U.S. power plants will be required to revert to using cooling towers, which will create new opportunities for the industrial water treatment industry.

The biggest global water user: agriculture

How about irrigation water savings in the United States and especially in California? How do we compare with other populous countries? Around the world, and especially in newly developing countries, surface and flood irrigation is the most common agricultural watering method used; water control is manual and induces large variations in volumes of water applied per unit area. Thus, in most situations, the volumes of water used are overkill, uneconomic, and not sustainable.

In North India, the rivers are fed by snow melt, but the rivers in south India are seasonable. Nevertheless, India has, relative to many other countries, significant rivers and surface and groundwater, despite having just 4% of the world's freshwater, but 16% of the global population. However, India has a water crisis, which is predominantly a manmade problem, and is due to poor management, unclear laws, government corruption, and untreated industrial and human waste. So the available water is often of no practical benefit because it is so polluted. Today, a rapidly growing economy and a large agricultural sector have stretched India's supply of water even thinner. Overpumping has simply added to the problems. Thus, access to water, especially good-quality drinking water can be very difficult. This problem is made worse by the fact that half of India's water supply in rural areas is routinely contaminated with toxic bacteria, leading to disease and death, especially of children.

Agriculturally, China produces more rice, wheat, potatoes, tomatoes, peanuts, tea, pork, and fish than any other country in the world, but it has over 300 million agricultural workers (a hundred times more than in the United States). Also, as a result of overexploited and polluted rivers and lakes, farmers are pumping so much aquifer water that groundwater tables are falling by more than 2 meters (6 feet) per year. This practice is unsustainable.

In the United States, the fact is that irrigation water supplies and pricing varies considerably across the country. Most agricultural irrigation occurs in the arid western states (80% of total water surface and groundwater withdrawals), where rainfall is insufficient for producing many crops. Compare this with agricultural withdrawals of 30% of total withdrawals in the South, and only 3% of withdrawals in the north central and eastern United States! Thus, prices and costs for irrigation water vary substantially with geographic location, water sources, and institutional arrangements (water rights). Some farmers with riparian water rights ("senior rights" because they are located next to a river or lake and staked a first claim) or exchange agreements with the federal government receive water at perhaps only \$5–\$10 per 1,000 m^3 (264,000 gallon), while other farmers with only "junior rights" may have to pay \$20–\$100, and maybe much more at the end of the season. Residents and manufacturing firms in some cities may have no water rights at all.

In recent years, rising energy costs and declining water levels have motivated very many farmers in the United States to save water by replacing field flooding and other surface irrigation methods with more costly (but water-saving) center-pivot or low-pressure sprinkler systems. From there, many farmers have moved on to even more expensive (but even lower water-consuming) surface and subsurface drip irrigation systems. Federal and state subsidies have helped pay for the high capital costs of drip irrigation. There is probably not a lot more that farmers can do to save water—especially in the western United States. And now, because of the extreme drought conditions in California, the state government may have to think about a more equitable way to share and distribute water than the current and very complex system of water rights, especially as the state has handed out water rights to five times more water than is available in an average year.

The good news is that very many farmers in California and some other U.S. states have moved extensively to very efficient micro-irrigation systems (surface drip, sub-surface drip, and micro-sprinklers). Water only goes to root zones, decreasing evaporation, run-off, and weeds. This leads to optimal growing—sometimes up to 25% increased production, but capital costs are very high (typically, $1,000/acre and $120/acre for annual upkeep). Government subsidies can help pay for much of the capital cost. Deficit irrigation is also practiced and refers to the practice of applying water below plants evapo-transpiration requirements, and of specific application times during critical growth phases, which gives maximum yield and minimum water usage. Some AWT member companies have now redirected their efforts to working with those farmers using micro-irrigation systems. They provide water treatment polymers, as well as chelants, specialist fertilizers, biocides, and filtration schemes, for water viscosity and friction reduction. Additionally, they can provide real-time water treatment data collection and management and advice on best practice water quality and water usage.

Purple pipes

California Title 22 ("The Purple Book") is the U.S. "gold standard" for laws on recycling water. Treated reclaimed water is now commonly reused as makeup for cooling towers; truck washing; watering of golf courses, parks, and road medians; firefighting; filling lakes; and irrigation of crops, commercial nurseries, and grazing pastures. It typically flows through purple pipes so it can be distinguished from other utility lines. Reclaim and reuse is more common with high-volume industrial water users, such as food and beverage. Here, we might see wastewater flowing to an equalization tank, with DAF and dewatering to recover fats, and then on to

biodegradation using sequential batch reactors (SBR) and anaerobic digestion (which produce methane as an energy source to power the pumps), followed by UF, MBR, and/or RO, and finally UV disinfection.

Overall, however, the United States has dropped the ball on promoting water reuse, accounting for less than 1 percent of total water usage in the country, and yet in coastal areas, an estimated 12 billion gallons of treated wastewater are simply discharged into the ocean or estuaries each day. This treated wastewater is suitable for reuse and is equivalent to 27 percent of current public water supply needs! Even Spain reclaims and reuses 17% of its wastewater!

In fact, Israel is the world leader in the use of purple pipes and reclaimed water. Seventy percent of its sewage, and 100% of the sewage from the Tel Aviv metropolitan area, is treated and reused as irrigation water for fields and public works. In the past, 70% of freshwater resources were used for agriculture, whereas today, it is down to only 40%. Also, Israel now has a lot more freshwater due to its forward thinking in the construction of seawater desalination plants.

In Singapore, 50 percent of water supplies are imported from neighboring Malaysia, but this figure was at one time nearly 100% and continues to decrease each year, as almost all rainwater is now collected through a network of drains, canals, rivers, stormwater collection ponds, and reservoirs, where it is treated and reused. Again, forward planning has meant that after only one decade, this reuse program meets 30 percent of Singapore's water needs; the plan is to triple the volume by 2060.

"NEWater" is the brand name given to reclaimed water produced by Singapore's Public Utilities Board. The water is purified using microfiltration, RO, and UV. It is potable and finds its way into public drinking water systems and in bottles at the local 7-11, and is also sent to those industries needing high-purity water.

The United States faces many water and energy challenges in the coming years! There are 15,000 municipal wastewater treatment plants in the country and 52,000 drinking water plants of various capacities. And almost all need significant repairs and upgrades.

- The United States faces a water supply-demand imbalance that must be resolved, in addition to an unsustainable funding gap. A trillion dollars is needed over the next two decades just to rehabilitate existing water infrastructure.
- Impacts are now being felt across industries due to increasing water scarcity, aging infrastructure, increased water pollution, climate volatility, water quality issues, and rising water-related energy risks.
- Changes are needed on multiple fronts—regulation, supply side, and demand side and more innovation to improve the long-term viability of water systems while decreasing consumption and reducing pollution.
- As part of our water infrastructure rebuild, I see a mix of consolidation of utilities, public-private partnerships, tax incentives, institutional investors, and strategic acquisitions by global players such as ABB, Acciona Aqua, AECOM, Arup, Bechtel, Black & Veitch, CH2M-Hill, Chicago Bridge, Clean Harbors, Inc. Doosan, DOW, Fluor, GE Water, Grupo ACS, Hochtief, IDE, KBR, MHW, GWE, RWL, Sumitomo, SWCC, Tetratech, URS Corp., Veolia, Suez, Xylem, and many others.

If we look at these wastewater treatment and drinking water plants, there are commonalities, in that most require upgrades in five key areas to meet the challenge of maintaining progress in potable water and wastewater pollution abatement ahead of population growth, changes in industrial processes, and technology developments; these areas are:

- Stricter regulations on wastewater nutrient removal to protect receiving water quality and provide for increase demands for water reuse.
- Improved energy management to meet twin goals of reducing greenhouse gases and conserving energy despite rising demands.
- Better resource management and water/energy recovery to meet the sustainability needs of future generations.
- New or advanced treatment and removal methods to manage rising concentrations of emerging contaminants
- Community engagement and fostering of transparency, good neighbor relations, and the end of *Not In My Backyard* (NIMBY) sentiments.

The fact is, that despite droughts; inequalities in global water distribution; and a trend toward water conservation, reclamation, and reuse, the total demand for access to water resources on the planet will continue to grow in the coming years, and energy needs will likewise, increase in parallel. Demands for water will be met largely by brackish and seawater desalination. The United States now has two medium sized RO desalination plants in Tampa Bay and El Paso, some smaller and virtually unused plants in Yuma and Santa Barbara, and a great many relatively small plants in Florida. The biggest U.S. SWRO plant, at 50 MGD, is currently being built by a Poseidan/IDE consortium in Carlsbad, California, and is due to come online in 2016, but at a final cost estimated to be about $1 billion.

If we compare California (38 million residents), with its sea coast, deserts, high mountains, and the highly productive Central Valley food growing region, with the state of Israel, we find that Israel has an almost identical topography, a similar food-growing region (the Jordan Valley), and also very little rain. This small country was founded in 1948 and has only 8 million people, but it has a freshwater generating capacity of over 500 MGD by seawater desalination (SWRO)—mainly in Sorek, Hadera, Ashkelon, Palamachim, and Asdod. The Sorek plant became operational in 2013 and produces 165 MGD (264,000 m^3/day)—more than three times as big as Carlsbad—and at a total investment of only 40% that of Carlsbad ($400 million)! It is instructive to learn that 50% of all freshwater in Israel is from SWRO, which permits almost all of the reclaimed water available in the country to be reused through its ubiquitous purple pipes for irrigation and similar duties.

The capital costs for SWRO trains are considerably reduced in Israel's newest plants, as 16" membranes are employed rather than the usual 8", which cuts requirements for frames and piping by up to 75%. The 16" modules have 4.3 times as much active area than 8" modules and thus, produce 4.3 times as much permeate, so fewer trains are required. Couple this cost savings with the latest energy recovery systems, which can reduce overall energy consumption by up to 60%, and we find that these new, variable demand/supply SWRO plants can profitably sell their product to the water authorities for $0.58/$m^3$ ($2.20/1000 gallon). This is the cheapest RO drinking water in the world!

The future of water usage and water treatment

As mentioned earlier in this article, globally, we should expect to see more seawater desalination (with continuous improvements expected with energy recovery systems and membrane types) and greatly increased numbers of industrial and agricultural water reuse projects. Also, we should expect to see realistic and multi-tiered pricing to discourage waste of both water and energy! We should also expect significant changes in water/energy management control systems to reduce consumption, reuse more water, and create irrigation and industrial sustainability.

There are many novel technologies for our new and rebuilt future potable water and wastewater treatment plants that are currently finding their way into the water infrastructure, including:

- Separation of stormwater flows from sewer water and in-plant wet weather management
- Continuous membrane filtration systems based on MF, UF, NF, FO, RO, MBR, and EDI
- New cloud-based, real-time information and communications technologies (ICT)

- Improved energy automation and pump control optimization systems.

Membranes will become the globally dominant water treatment technology, and desalination by RO will take a much firmer hold in the United States. Desalination is capital and energy intensive but is quickly becoming much less so! There is still much efficiency optimization development work to be undertaken with SWRO, to include improving recovery rates, flux distribution, permeate spacer devices, and seals; developing better and safer loading and unloading membrane tools; and data gathering and communications. Also, novel water treatment chemistries to further reduce biological fouling and scaling rates and manage intractable problems like clays and high silica water, and chemical water treatment to improve the cleanability of RO systems. Nevertheless, as with other areas of water treatment, evolving water treatment technologies will continuously provide for novel solutions to conserve water and energy resources and maximize operational outputs. Finally, regional water treatment chemical service companies—wherever in the world they are based, will have to upgrade themselves and become total water solution providers, face a shrinking traditional chemicals marketplace, or perhaps face extinction.

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