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Rethinking the water cycle

How moving to a circular economy can preserve our most vital resource.

Martin Stuchtey

Three billion people will join the global consumer class over the next two decades, accelerating the degradation of natural resources and escalating competition for them. Nowhere is this growing imbalance playing out more acutely than the water sector. Already, scarcity is so pronounced that we cannot reach many of our desired economic, social, and environmental goals. If we continue business as usual, global demand for water will exceed viable resources by 40 percent by 2030.

Many experts have claimed that wasteful treatment of water results from dysfunctional political or economic systems and ill-defined markets. But the real issue is that water has been pushed into a linear model in which it becomes successively more polluted as it travels through the system, rendering future use impossible. This practice transforms our most valuable and universal resource into a worthless trickle, creating high costs for subsequent users and society at large. Since the linear model is economically and environmentally unsustainable, we must instead view water as part of a circular economy, where it retains full value after each use and eventually returns to the system. And rather than focus solely on purification, we should attempt to prevent contamination or create a system in which water circulates in closed loops, allowing repeated use. These shifts will require radical solutions grounded in a complete mind-set change, but they must happen immediately, given the urgency of the situation.

A new, 'circular' perspective on water management

The global water crisis is real and graphically manifest. It's apparent in rivers that no longer reach the sea, such as the Colorado; exhausted aquifers in the

Arabian Peninsula and elsewhere; and polluted water sources like Lake Tai, one of the largest freshwater reserves in China. The root of this challenge is the violation of the zero-waste imperative—the principle that lies at the heart of any circular economy. It rests on these three basic beliefs:

- All durables, which are products with a long or infinite life span, must retain their value and be reused but never discarded or down cycled (broken down into parts and repurposed into new products of lesser value).

- All consumables, which are products with a short life span, should be used as often as possible before safely returning to the biosphere.

- Natural resources may only be used to the extent that they can be regenerated.

Even countries with advanced water-management systems violate these fundamental rules. They often fail to purify water before discharging it back into the environment because cleanup costs are high or prohibitive, even when energy or valuable chemicals could be extracted. The substances contained in the water then become pollutants. Equally troubling, any volume of water removed from the system is seldom replaced with return flow of the same quality.

When considering a redesign that will create a new, circular water system, we can take three different views:

- the product perspective, which calls for a strict distinction between water as a consumable and water as a durable, since there are different strategies for reducing waste in each category

- the resource perspective, which calls for a balance between withdrawals and return flows

- the utility perspective, which focuses on maximizing the value of our existing water infrastructure by increasing utilization and ensuring better recovery and refurbishment of assets

Water as a product

If we consider water to be a product—something that is processed, enriched, and delivered—we must follow the same strict design rules applied to any other product in a circular economy.

When water is treated as a durable, it should be kept in a closed loop under zero-liquid-discharge conditions and reused as much as possible. The major goal is not to keep water free of contaminants but to manage the integrity of the closed-loop cycle. Situations that favor the durable view include those in which it would be too costly to dispose of the solvents and re-create them—for instance, when water contains highly specific water-born solvents, electroplating baths, acids, and alkaline solutions used in heavy-duty cleaning. The Pearl Gas to Liquids complex in Qatar, for example, requires large volumes of water to convert gas to hydrocarbon liquids, including kerosene and base oil. To help prevent waste in a country plagued by shortages and droughts, the complex has a water-recycling plant—the largest of its kind—that can process 45,000 cubic meters of water per day without discharging any liquids.

When water is treated as a consumable, it must be kept pure and only brought into solution or suspension with matter that is easy or profitable to extract. For instance, consumable water should not be mixed with estrogenic hormones, toxic ink found on poor-quality toilet paper, or textile dyes. All water, including freshwater and gray water (household waste water still fit for agriculture or industrial use), should flow into subsequent cascades, where it may be used for another purpose. Whenever possible, energy and nutrients should be extracted from consumable water; there are now many revolutionary new techniques to help with this process, as well as other innovations that encourage reuse. Consider the following:

Our ability to extract energy. It is now commercially viable to generate heat and power from sludge and other organic wastes through thermal hydrolysis, which involves boiling them at high pressure followed by rapid decompression. This process sterilizes the sludge and makes it more biodegradable. Facilities at the forefront of this movement include the Billund BioRefinery in Denmark.

Our ability to extract nutrients. We can now recover a wide variety of substances from water, reducing both waste and costs. For instance, the potassium hydroxide that is used to neutralize the hydrofluoric acid in alkylation units can be extracted, decreasing costs for this substance by up to 75 percent. Substances can also be removed from sludge, such as polyhydroxyalkanoates and other biodegradable polyesters. The technology has advanced so much that value can be obtained from substances that were formerly only regarded as contaminants. For instance, ammonia removed from water can be used in the production of ammonium sulfate fertilizer, rather than simply discarded.

Our ability to reuse water. We are witnessing significant improvements in membrane-based treatments that separate water from contaminants, allowing for reuse and commercialization at grand scale. Many types of water benefit from this treatment, from gray water to Singapore's branded NEWater, which is high-grade reclaimed water. In fact, NEWater is so pure that it is mainly used by water-fabrication plants that have more stringent quality standards than those used for drinking water. In addition to innovative membrane-based technologies, experts have developed new source-separation systems that reduce mixing between chemical-carrying industrial and household waste water, making purification easier.

Although we should celebrate these improvements in treating water and safely returning it to the system, the creation of a truly circular economy will eventually require even more radical solutions. Achieving this would require the prevention of impurity and contamination in the first place. In the European Union, for instance, 95 kilograms of nitrate per hectare are washed away from fields into rivers (an amount higher than the 80 kilograms allowed). Discontinuing this process would reduce both waste and contamination.

Water as a resource

Water can come in the form of a finite stock or a renewable flow. As one example, water used for agriculture in Saudi Arabia comes almost exclusively from fossil aquifers that will be depleted in a few decades. Since these stocks are difficult to regenerate, future Saudi agriculture efforts must eventually involve new irrigation sources, such as gray water, and follow more stringent guidelines for reducing waste.

Luckily, most hydrological systems are flow systems—rivers or replenishable aquifers. Water from such systems can be withdrawn or consumed as long as the volume taken does not exceed the minimum "environmental flow" required to keep the ecosystem intact, or the natural replenishment rates. You cannot be more circular than managing the water balance of a river basin in a rigorous and integrated fashion. Investing in strategies that promote the vitality of a watershed are also circular, including those that involve better forest management (protection, reforestation, and forest-fuel-reduction programs that help control or eliminate wildfires), improved agricultural practices (such as no-tillage farming), and restoration of wetlands. The list of highly successful watershed-protection programs is long, ranging in location from New York's

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Catskill Mountains to Bogotá, and many additional opportunities exist.

Technologies that help balance supply and demand can also help water (both stock and flow) become part of a circular model. These include drip-irrigation systems that promote conservation by directly delivering water to root zones, irrigation scheduling, new technologies for steel dedusting that use air instead of water, and the application of Leadership in Energy & Environmental Design principles, which mandate inclusion of water-saving devices.

Water as an infrastructure system

Our global water networks and treatment plants, which are worth approximately $140 billion, consume about 10 to 15 percent of national power production. Following the principles of a circular economy, we must maximize the benefits over these deployed assets. These approaches may help:

Using existing assets for more services. Utilities have many options here. For instance, they could allow telecommunication companies to install fiber cables through their trenches for a fee and then charge for their maintenance, or they could use their sewage systems and wastewater-treatment facilities to collect and treat preprocessed food waste with sewage sludge. Using the latter technique, New York State has begun a program that has the potential to process 500 tons of food waste daily, generating heat for 5,200 homes. Utilities could also provide their data to governments or other interested parties for use in various initiatives, such as those related to healthcare or flood management.

Selling performance, not water. Instead of selling water and charging by the cubic meter, utilities could pay consumers for curbing use and then sell the conserved volume—termed "nega water"—back to the system. Such an effort, and similar initiatives, would also require a major overhaul of rate-setting mechanisms. Utilities should also promote conservation by selling double-flush toilets and similar devices, or by offering different levels of service, pricing, and convenience, with the goal of encouraging consumers to reduce use. As such, there should also be rate-setting mechanisms in place to encourage utilities to undertake water-conservation efforts.

Driving asset recovery. Utilities should establish asset-recovery centers and create procedures that promote reuse of equipment. This would include standardizing their pipes and meters to ensure they can be easily recovered and refurbished. Utilities should also begin tracking assets, which will allow easier reuse of equipment.

Optimizing resource efficiency. Finally, utilities should invest in ever more efficient operations and use green power, ideally generated in-house, whenever possible. They should be given incentives for doing so—something that does not typically happen today. There are many examples where anaerobic digestion of sludge alone produces biogas that covers more than 60 percent of energy consumed at wastewater-treatment plants.

Next-generation moves for water-system management

Innovators, responsible operators, and committed system developers are spearheading the creation of new technological solutions, pilot cases, and initiatives to improve water management. Many of the technologies are already generating profits or will be soon. These include the bespoke polymers that are created during the biological digestion of wastewater, as well as vapor-transfer irrigation systems that use low-cost plastic tubes that allow water vapor to pass but not water or solutes, making saltwater irrigation possible.

Equally important, leaders are also rethinking their institutional approach to water management. Many of their solutions are only being applied at small scale, however, and this must change over the next ten years to meet the water-resource challenge. So how can the water sector drive the much-needed system-level transition from today's linear model to tomorrow's circular design? What are the attractive, integrated plays? Five ideas stand out:

Product-design partnerships. Even in 2015, there is no dialogue between producers—say, of atrazine herbicides, antimicrobial disinfectants, or detergent metabolites—and wastewater operators. Their relationship resembles that between a distant water source and a sink, with diluted accountabilities. As the cost of treatment mounts, pressure will increase on producers to reduce contamination, especially as new technologies make it easier to identify their source. Shouldn't wastewater operators help by offering their expertise to producers and initiating product-design partnerships to ensure that water stays pure after use?

Resource-positive utilities. Wastewater utilities are ubiquitous, visible, and largely similar. They could soon become energy positive thanks to technical advances related to sludge methanization, waste-heat recovery, potassium hydroxide reduction, or on-site distributed power generation. Who will champion further advances, including those that aim to convert wastewater to energy, integrate grids, and recover nutrients?

Management for yield. Water is a powerful driver of yield in almost any industrial process and the extraction of raw materials. Improved site-level water management can increase beverage yields by 5 percent and oil-well productivity by 20 percent, largely benefitting the bottom line. It can also convey many other advantages, such as reduced heat or nutrient loss during processing. Taken together, these advantages can turn water into a major value driver. For instance, one pulp-and-paper producer discovered that it could improve margins by seven percentage points through better water management, leaving a much more circular operation behind. Who will help other companies find such value?

Basin management. From Évian-les-Bains to Quito, floodplain protection is a viable method for reducing the risk of flooding and preventing freshwater contamination. But attempts to improve basin management often fail because they require sophisticated multiparty contracts and a deep knowledge of hydrology and engineering. Who will help connect interested parties and minimize the bureaucracy associated with basin-management agreements?

Local organic nutrient cycles. Most communities are struggling to handle low-quality sludge and fragmented, contaminated streams of organic waste coming from households and businesses. Simultaneously, agriculture experts are exploring new sources for nutrients, since mineral fertilizer will soon be in short supply. If we aggregate local organic waste flows, we could help communities deal with their problem while also creating vibrant local markets for fertilizer components. Who will create and manage the local organic-nutrient cycle of the future?

Each of these plays represents a new way of looking at water and represents a huge business opportunity. They provide the industry with a chance to reposition itself and develop a new generation of designers, power engineers, yield managers, ecosystem-services marketers, or synthesis-gas tycoons.

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The shift to a circular water economy holds much promise. It would replace scarcity with abundance and greatly reduce the resources needed to run our global water infrastructure. At some point, a circular water economy might even eliminate rapidly growing cleanup costs because no harmful substances would ever be added to the water supply. Since water is the single most important shared resource across all supply chains, and wastewater is the largest untapped waste category—as big as all solid-waste categories taken together—it is the natural starting point for the circular revolution. The water sector's advanced technologies and proven record of multistakeholder agreements also lend themselves to circular solutions. We must capture this unique opportunity now, before localized droughts and shortages become a global crisis. ■

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