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THE HAMILTON PROJECT

Stanford WOODS INSTITUTE for the ENVIRONMENT

The Path to Water Innovation

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THE HAMILTON PROJECT

MISSION STATEMENT

The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth.

We believe that today's increasingly competitive global economy demands public policy ideas commensurate with the challenges of the 21st Century. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by fostering economic growth and broad participation in that growth, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments.

Our strategy calls for combining public investment, a secure social safety net, and fiscal discipline. In that framework, the Project puts forward innovative proposals from leading economic thinkers — based on credible evidence and experience, not ideology or doctrine — to introduce new and effective policy options into the national debate.

The Project is named after Alexander Hamilton, the nation's first Treasury Secretary, who laid the foundation for the modern American economy. Hamilton stood for sound fiscal policy, believed that broad-based opportunity for advancement would drive American economic growth, and recognized that "prudent aids and encouragements on the part of government" are necessary to enhance and guide market forces. The guiding principles of the Project remain consistent with these views.

ADVISORY COUNCIL

The Path to Water Innovation

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OCTOBER 2014

NOTE: This discussion paper is a proposal from the authors. As emphasized in The Hamilton Project's original strategy paper, the Project was designed in part to provide a forum for leading thinkers across the nation to put forward innovative and potentially important economic policy ideas that share the Project's broad goals of promoting economic growth, broad-based participation in growth, and economic security. The authors are invited to express their own ideas in discussion papers, whether or not the Project's staff or advisory council agrees with the specific proposals. This discussion paper is offered in that spirit.

BROOKINGS

Abstract

For more than a century the United States' water system has been one of the most reliable in the world. Today, it provides sufficient water to support over 315 million people, almost 55 million acres of irrigated farmland, and a $16 trillion economy. Yet the water sector faces increasing pressures. Growth in population and the economy, along with urbanization and land-use changes, are threatening both water quality and the ability to meet water demand. Looking to the future, climate change is expected to further stress water systems in large parts of the country. Water infrastructure, by some measures the oldest and most fragile part of the country's built environment, has decayed.

Solutions to the country's growing water challenges lie, in part, with the development and adoption of new innovative technologies. Yet, in comparison to the electric power sector, investment in water innovation is extremely low. Indeed, investment by the savviest promoters of innovation—such as venture capital and corporate research and development—are strikingly low in the United States and globally when compared with other major sectors of the economy. This low investment helps explain low levels of innovative output, as measured by patent filings and other data. Adoption and dissemination of new innovations are also slow.

The primary barriers to innovation are related to the way that the many layers of governmental agencies and water entities manage the nation's water sector. Among the main management and policy barriers are (1) unrealistically low water pricing rates; (2) unnecessary regulatory restrictions; (3) the absence of regulatory incentives; (4) lack of access to capital and funding; (5) concerns about public health and possible risks associated with adopting new technologies with limited records; (6) the geographical and functional fragmentation of the industry; and (7) the long life expectancy, size, and complexity of most water systems. Although the last three factors are inherent to the water sector and hard to change, substantial policy reforms are feasible that could alter pricing, regulation, and finance in the water sector—all in ways that would encourage innovation.

We focus on several recommendations: (1) pricing policies that would both better align with the full economic cost of supplying water and decouple revenues from the volume of water supplied; (2) regulatory frameworks to create an open and flexible governance environment that is innovation friendly and encourages valuable new technologies; and (3) financing and funding mechanisms, such as a public benefit charge on water, that can help raise sufficient funds to implement innovative solutions. As has been demonstrated in the clean energy sector, implementation of these policy reforms would facilitate greater innovation in the water sector. In addition, we recommend the creation of a state-level water innovation vision that would identify state-specific innovation opportunities and policies, along with state innovation offices to help implement the vision across the many varied agencies and firms relevant to the sector. While we expect these state water innovation offices would become common, a small group of states with the greatest water challenges—such as California, Florida, and Texas, or a consortium of like-challenged states in a region such as the West—would begin the process. Based on the lessons learned, other states could follow.

Table of Contents

Chapter 1: Introduction

Water is indispensable to life and the nation's social, economic, and environmental well-being. For over a century the United States has enjoyed reliable and safe sources of drinking water and has virtually eradicated most water-borne diseases. Through conservation, water-scarce regions of the country have met the needs of growing populations and economies. Today, the nation's water systems provide sufficient water to support more than 315 million people, almost 55 million acres of irrigated farmland, and a $16 trillion economy.

Although they have been highly effective to date, the country's water supply systems are now on the cusp of new challenges that they are not prepared to meet. Despite significant gains in conservation in recent decades, pressures on water supply are mounting as the population grows. Water infrastructure—including dams, reservoirs, aqueducts, and urban distribution pipes—is aging: almost 40 percent of the pipes used in the nation's water distribution systems are forty years old or older, and some key infrastructure is a century old. On average, about 16 percent of the nation's piped water is lost due to leaks and system inefficiencies, wasting about 7 billion gallons of clean and treated water every day (U.S. Environmental Protection Administration [EPA] 2013; Maxwell 2013).

On average, about 16 percent of the nation's piped water is lost due to leaks and system inefficiencies, wasting about 7 billion gallons of clean and treated water every day.

Climate change will further threaten water supplies while increasing demand in some parts of the country. In areas such as the West that are already prone to drought, climate change is likely to shift storm tracks and thin snow packs (Pierce et al. 2008). In those parts of the country, droughts are likely to become worse and more prevalent (Cayan et al. 2010; Dai 2010). In coastal zones, the impacts of climate change will be felt through stronger storms and coastal flooding that could threaten the reliability of urban water supply systems (Bloomberg, Paulson, and Steyer 2014). Higher temperatures will also raise evapotranspiration rates, further increasing agricultural water needs.[1] At the same time, increasing environmental regulation is reducing the amount of water that can be withdrawn from the nation's rivers, lakes, and aquifers, and groundwater overdraft is impacting water availability in various basins (Zekster, Loaiciga, and Wolf 2005). The nation, in short, will need to do more with less.

New technologies can help the nation continue to grow in the face of scarcer water supplies. New water technologies can enable greater levels of economically affordable conservation and increase productivity of available water sources through increased efficiency, reducing overall demand for water. Water supply technologies that recycle or desalinate water can provide the nation with additional sources of water that are better insulated from drought and other pressures affecting traditional supplies. New water technologies also can help water managers better characterize and manage groundwater aquifers and complex river systems, permitting the nation to maximize the yield of its existing water sources. Contaminants of emerging concern and increasingly stringent drinking water goals call for new purification technologies that can help remove those contaminants and provide drinking water of even higher quality (e.g., Savage and Diallo 2005).

While the water sector offers many opportunities to innovate and deploy new technologies, in practice the sector has barely tapped the potential those technologies offer. Various hurdles currently inhibit the development, testing, adoption, and diffusion of new water technologies. Research and development (R&D) is a public good that is likely to be suboptimal in scale without public financial support—a problem also faced in other sectors of the economy such as the electric power sector (Nemet and Kammen 2007). Indeed, firms and regulators in the water sector could learn much by observing how other analogous sectors of the economy have addressed the need for new technology—yet very little of this cross-sectoral learning actually occurs in the water sector. Various barriers have inhibited fundamental change in recent decades in the basic technologies. Addressing the coming challenges will require new approaches.

We put forth a new strategy to increase innovation and deployment of new technologies in the water sector. Our proposal is threefold: First, we call for a change in the pricing of water to better match the economic cost of supplying water and to foster more private-sector innovation. Improper water pricing undercuts both the incentive for water-conserving technologies by water users and the financial stability needed to finance the adoption and implementation of new water technologies by the water suppliers. Second, we call for regulatory reforms at the subnational level to create a more innovation-friendly environment. As part of this recommendation we suggest that some states could benefit from the creation of new water innovation offices to coordinate and support pro-innovation policies. We argue that many current regulations frequently hinder the adoption of cost-effective technologies. Third, we call for a public benefit charge on water to allow for more public funding for water innovation. Taken together, these three major policy initiatives could dramatically improve technological innovation in water and lead to more-efficient outcomes in our nation's water sector.

Chapter 2: Background

THE WATER SECTOR

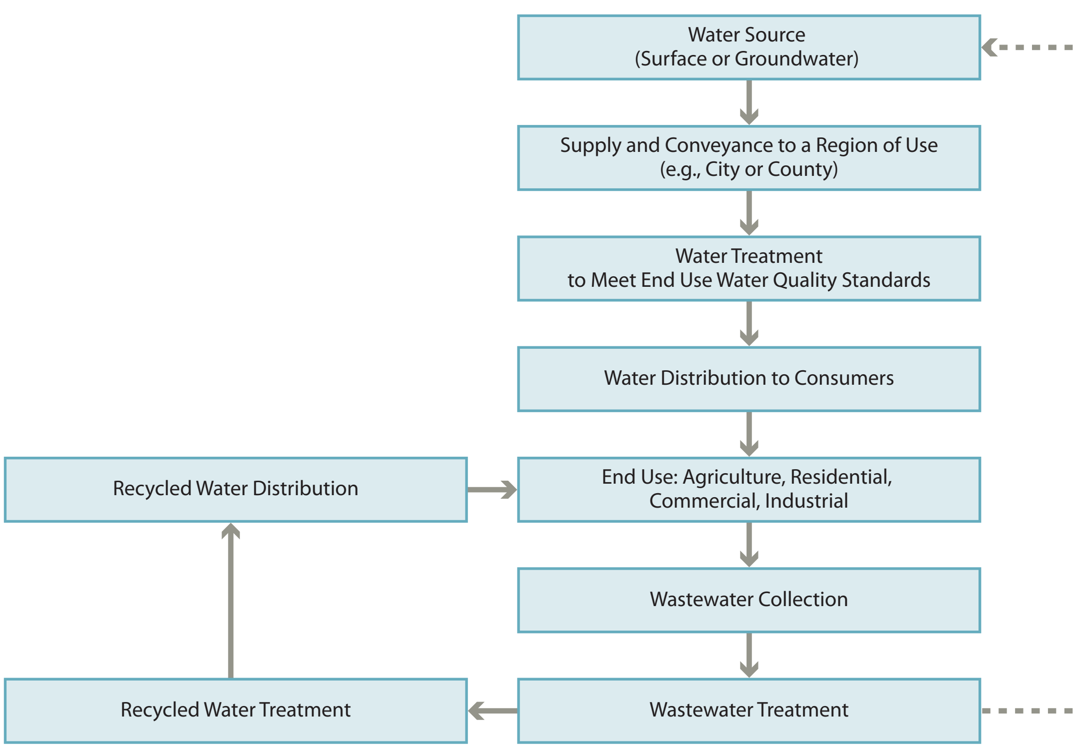
The water sector can be divided into a number of subsectors, including water supply, conveyance, treatment, and distribution; the consumptive or end use of water by agricultural, residential, commercial, and industrial users; the collection, treatment, and disposal of wastewater; and water recycling and distribution, which can also be considered a part of the water supply subsector. Water is extracted from a surface or groundwater source and conveyed to a water treatment facility to be treated and purified to meet end-use water quality standards before it is distributed to customers in various sectors such as residential or agricultural (figure 1). Subsequently, wastewater is collected from various sectors and transferred to a wastewater treatment plant for treatment to meet environmental water quality standards before it is returned to the environment (e.g., waterway, ocean, or aquifer). In some cases, a portion of the wastewater could be recycled—treated to a higher standard—and reused by a prospective end-user.

In many regions of the country, management of water supply and wastewater is fragmented by function. Water supply entities generally supply, convey, purify, and distribute water to a particular sector of the population or the economy. Wastewater entities generally collect, treat, and dispose of the wastewater.

The water sector is also geographically fragmented. According to the U.S. Environmental Protection Agency (EPA), approximately 155,000 drinking-water systems and 15,000 wastewater systems exist in the United States (EPA 2009). Many of these systems are small, particularly in rural regions. Diverse and highly localized technical, regulatory, and

FIGURE 1.

Water Distribution and Use Cycle



Source: Modified from The Climate Registry and Water Energy Innovations 2013.

institutional frameworks and policies have further added to fragmentation and complexity in the water industry.

Another key feature of the water sector is the dominance of publicly owned suppliers. This was not always the case. Privately owned companies distributed most of the water in the late eighteenth century and much of the nineteenth century. However, concerns over high water rates, inequitable distribution of water within urban communities, health risks from untreated water, and low levels of reinvestment in water systems led many cities to take over private water supply systems in the late nineteenth century. While private water suppliers still outnumber public suppliers in the United States, public suppliers today furnish water to about 80 percent of the nation's domestic and commercial users and almost 20 percent of its industrial users (Thompson, Leshy, and Abrams 2013). Public water agencies also supply the water needed to irrigate approximately a quarter of the irrigated acreage in the Western United States (and over half of the irrigated acreage in California and Washington), with most of the rest of the irrigation water obtained directly from waterways or aquifers by the farmer or rancher; private entities play only a small role in the supply and distribution of irrigation water (Thompson 1993).

Public water entities are seldom subject to regulation by state public utility commissions. As a result, local political processes provide the principal oversight of public water suppliers. Most public water suppliers are governed either by local government officials (e.g., members of city councils) or by elected boards (e.g., the board members of irrigation districts). In voting for such officials, members of the local public generally seek three goals: reliability, safety, and low water prices. Elections for water officials are seldom contested except where these goals are threatened.

As explained in more detail below, a number of these factors—high fragmentation, public ownership, political pressure for low water rates, and reliability concerns—as well as other issues, inhibit innovation. The past two centuries saw a handful of fundamental technological changes in the water sector, generally driven by health or environmental concerns. In the early nineteenth century, advances in water treatment enabled the delivery of safe, clean drinking water to the nation's growing cities, and helped protect populations from contaminants causing contagious diseases, thereby reducing disease rates in urban regions of the country (EPA 2000). The invention of sewage treatment plants in the early twentieth century led to greater protection of rivers, lakes, estuaries, and other aquatic ecosystems (Sedlak 2014). In the final decades of the twentieth century, passage of the Clean Water Act of 1972 (and its 1977 amendments) and the Safe Drinking Water Act of 1974 required further improvements in wastewater treatment and improved ambient water quality, along with marginal changes in the technology used for drinking-water treatment. Since then, however, the pattern of technological change in the sector has generally been marked by stagnation, although some innovative water entities such as the Orange County (CA) Water District have continued to pursue cutting-edge opportunities.

> The pattern of technological change in the water sector has generally been marked by stagnation.

COMPARISONS TO THE ENERGY SECTOR

Throughout this paper we draw comparisons with the energy sector—notably electricity—for several reasons. First, because the two sectors have many similarities in technological structure, such as the central role of long-lived infrastructures, comparisons of technological innovation can provide a relevant sense of the relative level of innovation in the water sector. Other economic sectors, such as biotechnology or information technology, have significantly different industrial structures and infrastructure turnover that is much more rapid, leading to different potentials for innovation. As described in more detail below in the section "Explaining Patterns of Innovation," comparisons between the water and energy sector are complicated, so any conclusions are highly conditional. Unfortunately, no simple and reliable measures of innovation in the two industries exist, and potential measures of innovation often cannot be directly compared from one industry to the other. By looking at multiple indicators, however, it is possible to triangulate on some general conclusions regarding the scale of innovation and the factors that can alter patterns of innovation.

Second, policymakers and researchers have focused much more on the policies that could increase innovation in the energy sector than on such policies in the water industry. As a result, the energy sector provides helpful lessons to the water sector in thinking about how technological innovation can be advanced. Many ideas for increasing innovation within the electric power sector have fallen short of their potential, which also offers important caveats about efforts, such as in this paper, to outline an innovation strategy for water.

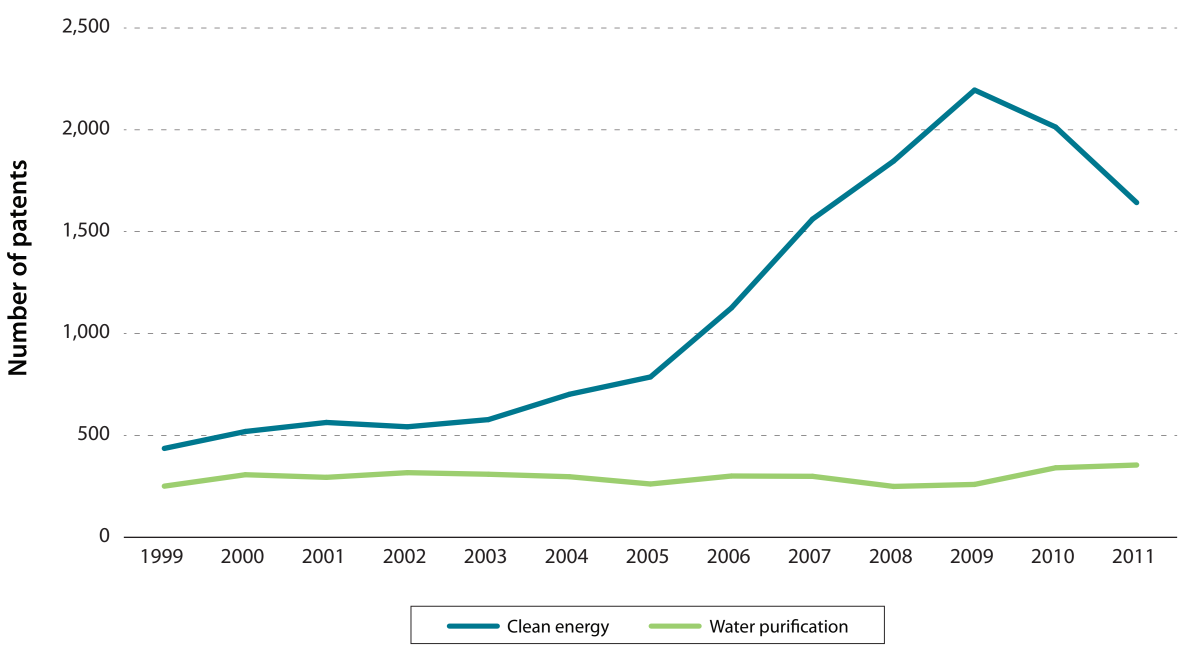
The similarities between the sectors are critical to understanding the lessons that water can learn from energy. The distribution and use cycles for both sectors depend on large-scale and capital-intensive infrastructures and complex governance models. Both involve high barriers to entry, which make segments of each industry prone to natural monopoly and low levels of competition. Both sectors also directly interface with consumers, providing services that are vital to individual, social, and economic well-being and, as a result, are often politicized. Both sectors are highly regulated and risk-averse, since any system failure could have immense social and economic impacts.

The two sectors, however, differ in some important traits, including the nature of ownership. As noted already, water suppliers in the United States are overwhelmingly dominated by publicly owned utilities, also known as state-owned enterprises (SOEs), with investor-owned public utilities supplying only a small fraction of the country's water.[2] In contrast, investor-owned utilities dominate in the energy sector (Besant-Jones 2006).

In some states, private competitive firms also play a role in the supply, transmission, and retailing of electricity, doing business alongside large, regulated utilities. While the electricity distribution system (the long networks of wires and transformers that link individual firms and households to the grid) remains a natural monopoly, many other services of the electric power industry have been unbundled from the monopoly and are now provided by competitive firms. In much of the United States competitive firms engage in the wholesale generation of electric power. In parts of the country, notably the regional transmission organization of the

FIGURE 2.

Comparison of U.S. Patents Filed under the Patent Cooperation Treaty for Clean Energy and Water Purification, 1999–2011



Source: Organisation for Economic Co-operation and Development (OECD) 2014.

Note: Clean energy = biomass generation + energy efficiency + energy storage + geothermal + hydro & marine power + solar + wind; and water purification is the primary contributor to patent filings in the water sector.

Northeastern United States, power lines are also competitive. In those settings, markets are used to encourage investment and operation of power lines as well as bulk power generation. In a few states, such as Texas, the open retailing of electricity has also been tried, although that part of the industry remains generally uncompetitive because consumers have not been particularly responsive to electricity retail competition.

Relative to the energy sector, there is a dearth of competition in the water sector. While private firms sometimes construct infrastructure or undertake particular operations in partnership with SOEs (e.g., the construction and operation of recycling or desalination plants), the role of those firms is highly circumscribed compared to the energy sector.

The two industries also differ in the geographic scale of attention they receive. Water is a local resource and its availability is subject to local climatic variability, patterns, and geographical realities. Most debates over water policy occur locally or at the state level with the exception of water quality. Power availability and supply, however, depend on regional, national, and international markets, and therefore sit high in national and international policy priority lists.

For these and other reasons discussed later, the water and energy sectors have followed significantly different paths of innovation. Using the numbers of patents filed in each sector as an indicator, the clean energy sector has exhibited a much higher rate of innovation over the past decade (figure 2).[3] This high level of innovation in the clean energy sector has been partly the result of strong policy drivers for alternative energy, including renewable power coupled to energy storage systems. Such drivers include state mandates to increase the supply of solar, wind, geothermal and other renewable energy supplies, as well as federal and state financial incentives. Without such policies the marketplace on its own probably would not have adopted such technologies at scale, especially after the middle of the 2000s, when the revolution in horizontal drilling and hydraulic fracturing drove the price of natural gas (and thus the marginal price of electricity) to low levels.

Chapter 3: State of Innovation in the Water Sector

The United States has the largest water market in the world (figure 3); it is also growing rapidly (Global Water Intelligence 2011; White et al. 2010). The global water market includes both water and wastewater sectors. Its budget is divided into capital expenditures, which cover capital spending on facility expansion and/or repair; and operation expenditures, which cover the cost of the cleaning, distribution, and collection of water and wastewater (White et al. 2010).

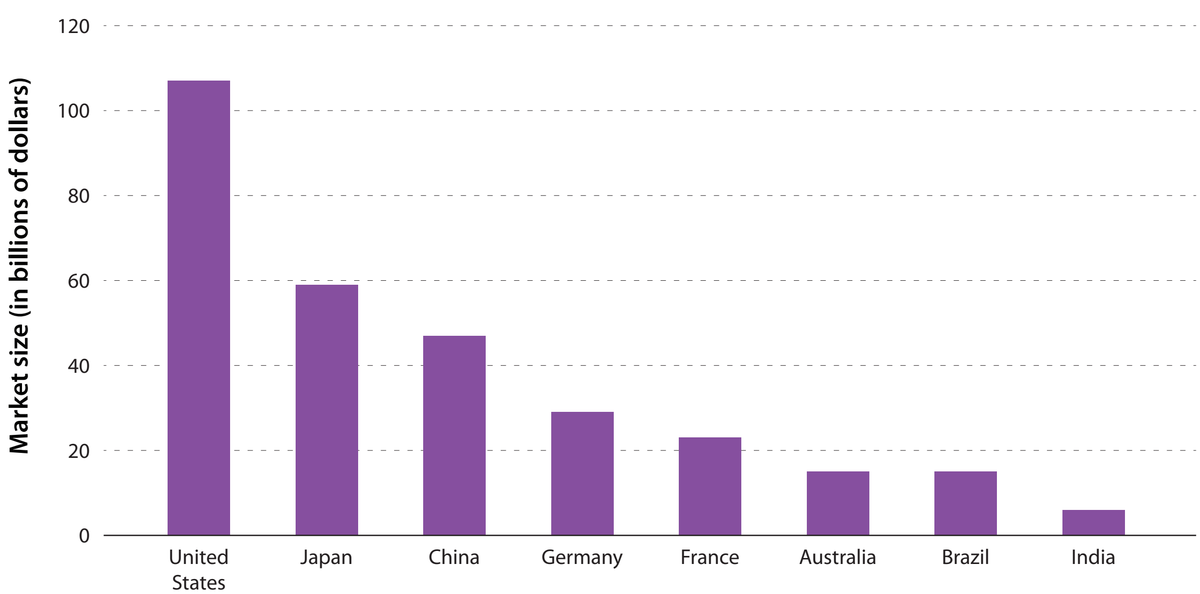
Globally, capital expenditures constitute between 35 and 45 percent of the water industry's expenses (White et al. 2010). According to the EPA (2006), about 53 percent of the water sector's capital spending goes to system expansion, followed by 37 percent for replacing existing infrastructure and 10 percent for compliance. While capital expenditures do not necessarily involve new technologies, new capital investment provides an opportunity for the installation of new technologies, especially in a country such as the United States with a rapid water market growth rate. Unfortunately, this opportunity has not translated into rates of innovation comparable to those in the electricity and clean energy sectors.

INNOVATION FRONTIERS IN THE WATER SECTOR

The ultimate goals of the water sector are to provide customers with reliable and safe water supplies and to dispose of wastewater safely and in compliance with water quality regulations. Several assumptions historically guided water managers in meeting these goals. First, water managers assumed that demand for fresh water would increase with population and that the only way to ensure a balance between supply and demand was to find new sources of supply. The focus therefore was on supply enhancement rather than demand management. Water managers, moreover, generally looked to large-scale, centralized infrastructure projects to increase supply, on the assumption that large-scale projects would generate significant economies of scale and provide greater operational flexibility (Ajami et al. 2012; Hering et al. 2013). As a result, supply enhancement often meant large dams,

FIGURE 3.

Size of the Major International Water Markets, 2010



Source: Global Water Intelligence 2010.

reservoirs, aqueducts, and water and wastewater treatment plants. Finally, while water managers in the Western United States worried about short-term droughts, they assumed that long-term conditions would remain relatively static; that is, they assumed that, if they designed water systems to meet current hydrologic conditions, those systems would also meet future conditions. Eastern water managers often discounted the risk of even short-term droughts.

Water managers are rethinking all these assumptions, and the new waterscape has opened up opportunities for a variety of new technologies. Rather than relying only on supply enhancement, water managers now are placing increasing emphasis on demand management. Studies demonstrate that new technologies, coupled with incentives and education, can greatly reduce water use. As a result, there is increasing interest in technologies that are more water efficient and in technologies that can help encourage greater conservation among consumers.

Extreme climatic events such as floods and droughts are testing the current resilience of many water systems, revealing their deficiencies and inefficiencies.

Hydrology, climatology, and geographic realities also have begun to undermine the view that long-term water conditions are largely static. Extreme climatic events such as floods and droughts are testing the current resilience of many water systems, revealing their deficiencies and inefficiencies. Climate change is also undermining long-term water supplies and the long-time assumptions of many water managers. As a result, water managers are looking for new technologies and approaches that are more resilient to change.

Finally, large-scale, centralized infrastructure projects are revealing a number of weaknesses. As energy costs rise, the expense of moving water tremendous distances and treating it has generated considerable concern. Because of the large amount of water and number of customers involved in large-scale projects, threats to such projects—whether from environmental regulations, earthquakes, climate change, or other challenges—have been magnified. As a result, there is increasing interest in smaller-scale, decentralized sources of water supply.

Three categories of innovative technology are of particular interest today:

1. **Supply enhancement.** As noted, the historically dominant strategy to meet water demand has been supply enhancement. Despite improvements in conservation and water-use efficiency, supply enhancement remains an important focus of water managers today. Water managers, however, are increasingly interested in technologies that promise more-drought-resistant water supplies, such as reclaimed water or desalination; or that can reduce energy use, such as recycling technologies that extract significant energy from wastewater. Water managers also are interested in technologies that allow more-localized resource enhancement strategies, such as rainwater and storm water capture, and small-scale water reclamation.

2. **Demand management.** As the focus of water managers shifts from supply enhancement to demand management, demand is increasing for technologies that encourage or enable water-use efficiency (i.e., achieving the same goal with less water) or water conservation (i.e., reducing water-consumptive activities). Such technologies can reduce the need for new supplies, increase water reliability, and decrease the costs and pollution associated with wastewater disposal. Examples range from water-efficient appliances to drip irrigation to smart irrigation controllers. Technologies that encourage behavioral change by water users, such as smart meters that enable water consumers to get a better real-time sense of their water usage, also have begun to play a bigger role in the water sector.

3. **Governance improvement.** New technologies also promise to improve overall water governance, which is essential to both securing access to reliable water supply and reducing demand. A wide range of innovative techniques are available at various scales to tackle inefficiencies in the governance system. Smart metering and advanced data collection methodologies, for example, can enable water utilities to more closely and accurately measure supply and track demand, and to identify leaks and other failures in the distribution system so they can be corrected quickly. Tools that enable assessment of customer behavior under various scenarios can improve resource planning and management. Advanced forecasting models are becoming a necessity in making supply planning more realistic.

These three categories cover a wide variety of technological innovations including:

- **Smart water.** Technologies that integrate information technology into water accounting and management, such as leak detection, smart water meters, and Internet-based water-use solutions and software. These innovative solutions enable water service providers to enhance supply and curb demand simultaneously.

- **Efficiency and conservation.** Technologies that enable short- and long-term demand management in various sectors, such as irrigation sensors, low-flow plumbing, and water-efficient appliances.

- **Purification.** All the technologies that are used to purify, filter, disinfect, and produce water of different quality for different beneficial uses.

- **Alternative sources.** Technologies with the potential of producing water from nontraditional water sources such as desalination, rainwater or stormwater capture, and reuse of wastewater. The largest industry sector in this category is desalination.

- **Storage (surface and ground).** Technological advancement that focuses on improving storage capacity above and below surface.

- **Groundwater.** Technologies that enable water infiltration and groundwater banking and recovery.

A variety of constituents and target markets, including water suppliers and various user groups (e.g., industrial, residential, commercial, and agricultural), have helped drive water innovation. Innovative activity in each category of solutions often corresponds with one or more target markets. For example, the food and beverage, pharmaceutical, and petroleum industries have helped drive two of the most rapidly growing technological frontiers in the water industry—desalination and water purification (White et al. 2010). Residential consumers have helped spur interest in water-efficient appliances. Yet, despite some advancement in various frontiers of the water sector, the rate of innovation dissemination has been slow. We next examine the pace of innovation in both the water and clean energy sectors.

EVALUATING PATTERNS OF INNOVATION IN WATER AND CLEAN ENERGY

It is difficult to measure exactly the state of innovation and the deployment of new technologies. The picture that emerges, however, indicates that water has not enjoyed the same pace of innovation as clean energy. This subsection examines innovation from the perspective of (1) investment trends, including overall patterns as well as investment by venture capital, corporate, and public sources; and (2) patents.

Innovation Indicators: Investment Trends

We used the Cleantech i3 database to evaluate investment trends in the clean energy and water sectors (Cleantech Group 2014). Clean energy data comprise the sum of several clean technology subsectors in the Cleantech investment database, including biomass generation; energy efficiency; energy storage; smart grid; and geothermal, hydro and marine, nuclear, solar, and wind power. Water data include smart water (smart metering and control, smart irrigation, and contaminant and leak detection), purification (wastewater treatment, and disinfection), desalination, and water conservation. While there are many ways to look at investment, the Cleantech database is the only one that offers systematic coverage of the technological frontier in both sectors.

Over the past decade, investments in clean energy have exceeded those in the water sector by an order of magnitude for all investment types, both globally and within the United States (figure 4). In the United States, investments are dominated by venture capital activity in both sectors, but especially in the water sector where venture capital and corporate ventures account for 53 and 24 percent, respectively, of total investment dollars (figure 4b). By comparison, investment banking is the largest global contributor to both clean energy and water, at 31 and 27 percent, respectively, of total investment dollars (figure 4a).

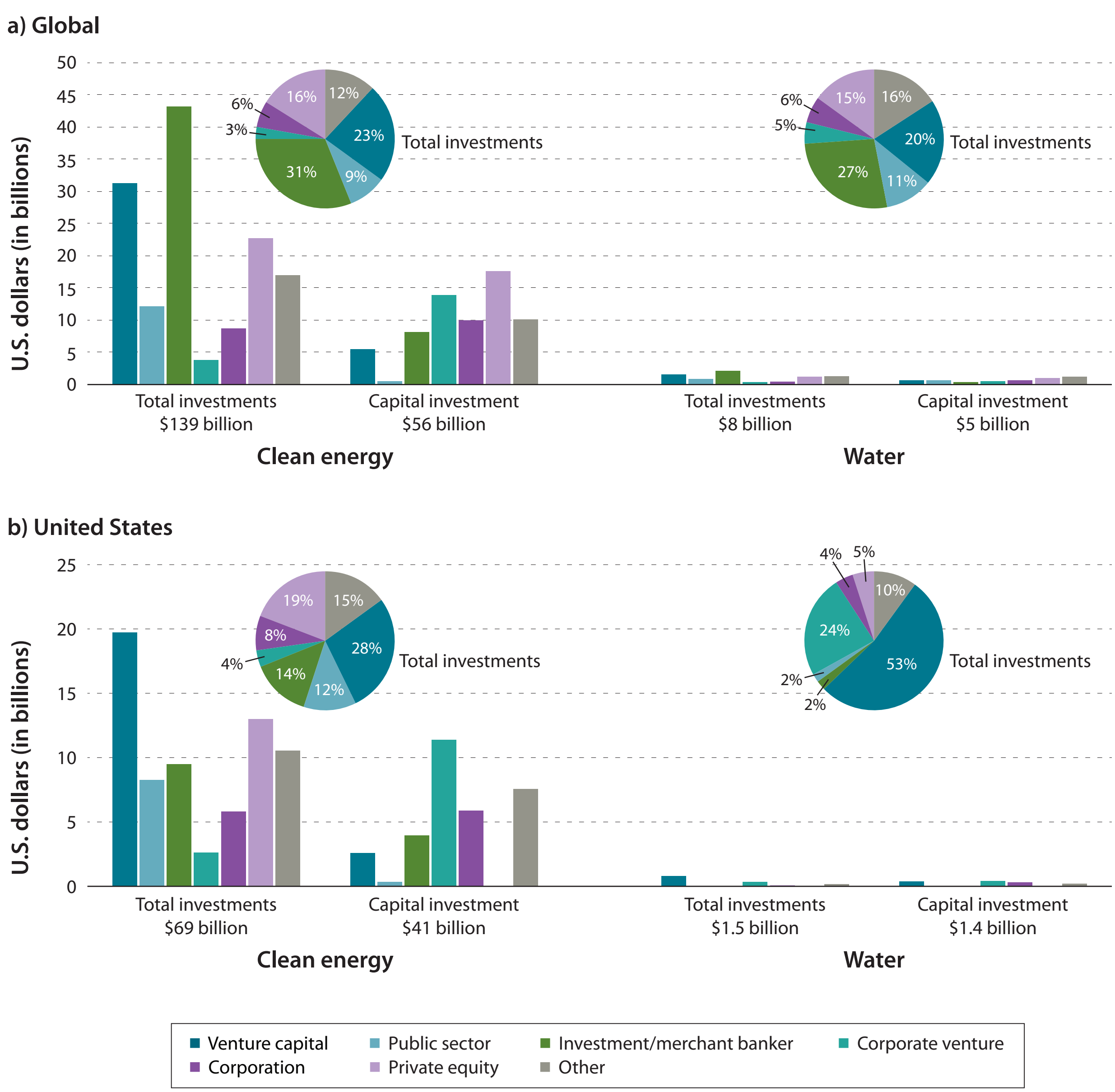
Despite differences in the overall magnitude of investment between clean energy and water, the relative proportion of global investment dollars by investor type is similar for both clean energy and water (figure 4a, pie charts). This pattern does not hold for U.S. investments (figure 4b, pie charts); significant clean energy investments come from all investor types, while corporate ventures and venture capital account for over three quarters of all water investments. Public investment in the water sector seems to be quite insignificant (figure 4b).

The number of investment deals is another useful indicator of innovation because it reflects the level of interest in a sector (figure 5). Deals are divided into venture capital, public sector (grants, contracts, and loans), investment/merchant banker, corporate ventures, corporations, private equity, and other. The United States accounts for approximately 50 percent of global investment deals in both the clean energy and water sectors, and venture capital accounts for the vast majority of deals at both the national and global scale.

Though venture capital investments are the most frequent form of deal, they tend to be smaller investments, especially in the water sector. There were 4,193 venture capital deals for clean energy, raising $20 billion at an average of $4.8 million per deal. By contrast, 372 deals raised $800 million in venture capital for the water sector, at an average of $2.2 million per deal (Cleantech Group 2014).

FIGURE 4.

Sources of Investment Dollars for Global and U.S. Innovation in the Clean Energy and Water Sectors, 2000–13



Source: Cleantech Group 2014.

Note: Clean energy = biomass generation + energy efficiency + energy storage + solar + wind + geothermal + nuclear + hydro & marine + smart grid; and water = water + wastewater.

The number of deals and level of investment from various types of investors are in part reflective of existing markets for the two sectors. Unless there is a healthy market that would accept and adopt the newly developed innovative solutions, the investors would not have much incentive to invest in that sector. This in a way highlights the earlier point we made about the end-user and target markets helping to create various innovative technological solutions.

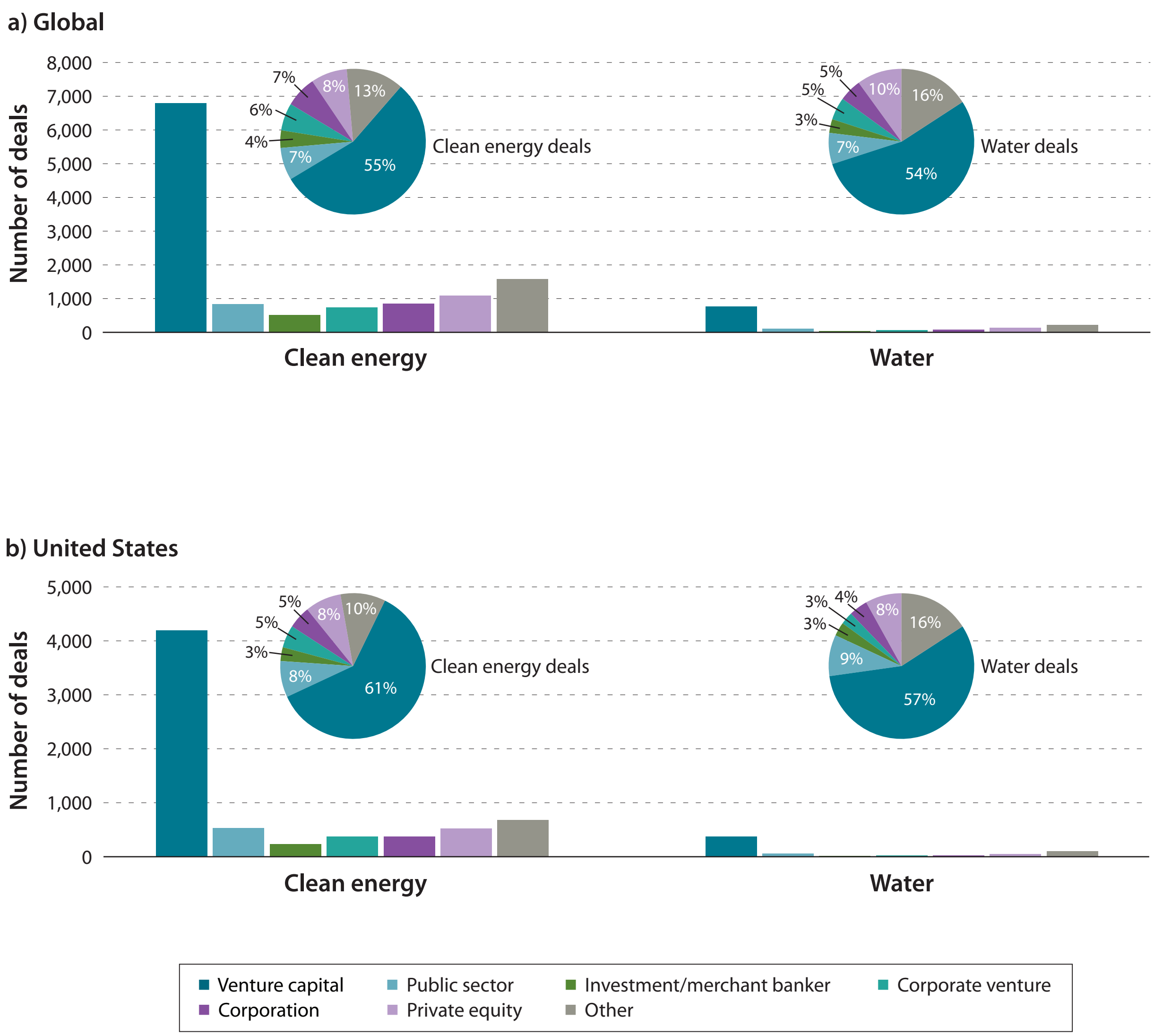
We next look in more detail at the investment trends by some of the key investor types in the water sector in the United States: venture capital, corporate investment (including both corporate venture and corporate investment), and public investment.

Venture Capital Investment

Venture capital investment is an important initial source of financing for new companies and can be a useful indicator of innovation level. Venture capital investment is particularly

FIGURE 5.

Number of Deals and Relative Contribution of Investment Types for Global and U.S. Innovation in the Clean Energy and Water Sectors, 2000–13



Source: Cleantech Group 2014.

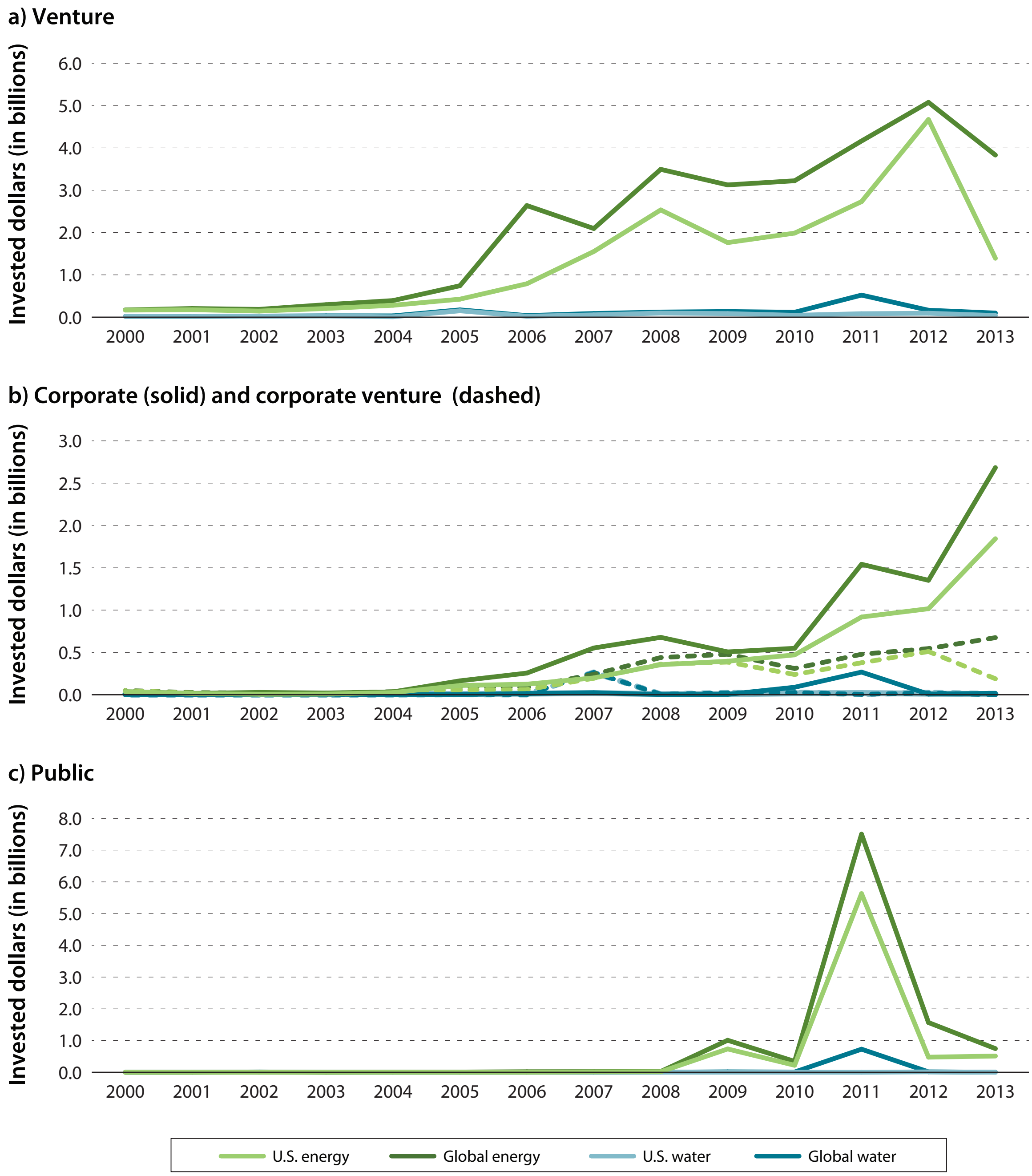
Note: Clean energy = biomass generation + energy efficiency + energy storage + solar + wind + geothermal + nuclear + hydro & marine + smart grid; and water = water + wastewater.

useful as a measure of high-value innovation because it is rooted in a business model based on the philosophy of identifying early stage investment opportunities in technologies with potentially high returns in a short timeframe. Under this business model, many water technologies are at a disadvantage in competing for venture capital funds (figures 4a and 4b), due to the risk-averse nature of the highly regulated water sector; the technologies require long testing and review periods before they can be adopted (Forer and Staub 2013).

The data presented here confirm this hypothesis. While venture capital represents the largest flow of investment in the water sector in the United States (about 53 percent; see figure 4b), it still claims a very small percentage of total Cleantech venture investments nationwide (about 4–5 percent). U.S. venture capital investment in water technologies, while showing a positive trend, is still very small compared to other sectors such as clean energy (figure 5b).

FIGURE 6.

Global and U.S. Investments in Clean Energy and Water by Venture, Corporate and Corporate Venture, and Public Sources, 2000–13



Source: Cleantech Group 2014.

Venture capital investments in both the water and energy sectors were relatively flat up to 2004 (figure 6a). However venture capital investment in the clean energy sector grew by a factor of five between 2004 and 2011. The water sector witnessed a very small growth in venture capital investment during those years. The growth in the clean energy sector was partly driven by the move toward clean energy and renewable energy portfolio standards and other more-aggressive energy policies, which eventually created a big market opportunity in the sector. Solar and wind power global market size has grown on average tenfold since 2004 (figure 7) (Shahan 2011).

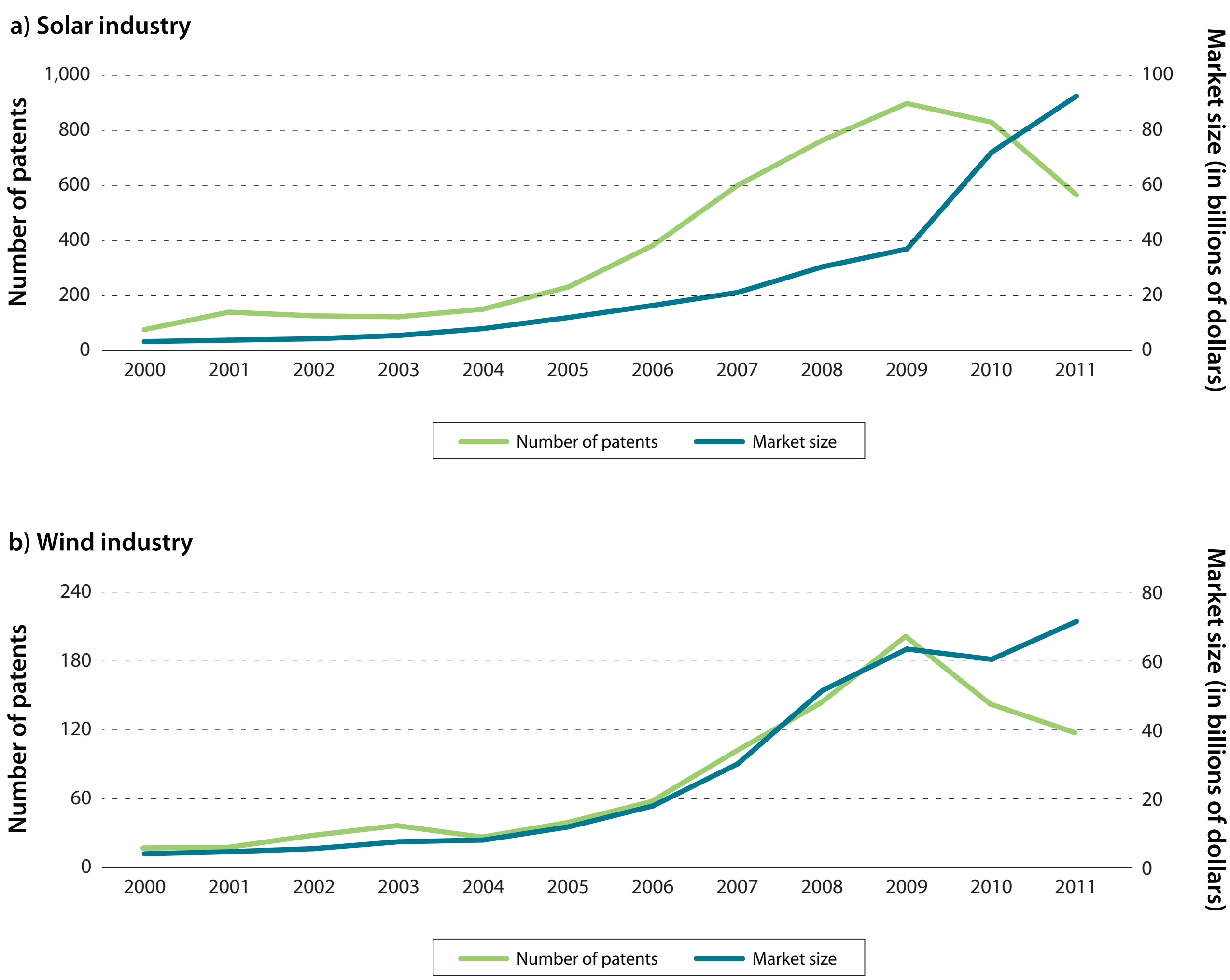
Corporate Investment

Corporate investment constitutes a significant share of overall funding in the water sector (see figure 4). Corporations both invest in internal R&D and provide venture capital funds for other companies developing new technologies. For corporations, venture investment in water innovation has two dimensions. First, some corporations might be seeking to improve their own internal operations. For example, food and beverage companies may wish to acquire new purification systems for their processes. Second, corporations might be looking for new market opportunities. These two goals separate corporations from venture capitalists, as their interest goes beyond groundbreaking technologies with potentially high financial return. Marginal advances in technology that could ultimately help their operational needs could be seen as a valuable investment for corporations.

Corporations are becoming increasingly interested in investing in innovative water supply and purification technologies (figure 6b), as access to clean water can affect their bottom line (Heslop and Faulkner 2013). Corporate interest in water technologies can create target markets that

FIGURE 7.

Number of Patents Relative to Market Size for Solar and Wind Power Industry, 2000–11



Source: Pernick, Wilder, and Winnie 2013.

help drive innovation in those areas. Corporate investment in the water sector is still lagging behind clean energy (figure 6b). Nevertheless, as water scarcity and stricter environmental regulations affect corporations, their interest in finding innovative solutions to meet their water demands and maintain growth will only rise, especially in high-growth industries such as oil and gas (Cleantech Group 2014).

Public Investment

A critical contrast between the water and clean energy sector investment trends is the level of public money (mostly R&D in the form of grants, contracts, and loans). According to the Cleantech Group data (2014), in the United States the clean energy sector has benefited from about $8 billion in public investment over the past thirteen years, while only $28 million in public dollars has gone to the water sector over the same period. The level of global public investment in the water sector is also an order of magnitude less than in the clean energy sector (figure 6c).

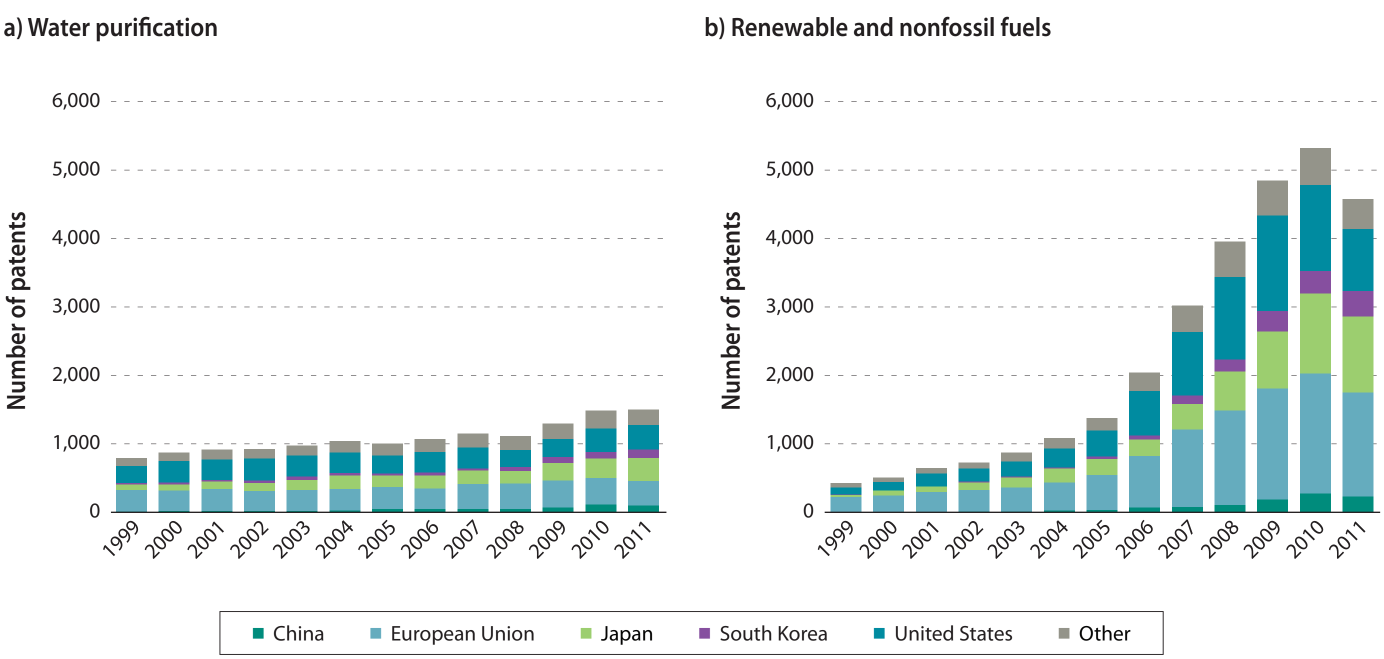
Public funding has proven to be of critical importance in the clean energy sector. None of the really big advances in the electric power industry—such as the rise of nuclear or gas generators—would have been possible without governmental funding. While it is hard to analyze the counterfactual, this story has been replicated so many times in the power industry as well as most other industries—for example, advanced computing (National Research Council 1999)—that it is probably robust. The critical role of public-sector funding, combined with the limited private-sector funding for innovation in the water sector, is one of the major factors behind the sluggish technological development in the U.S. water sector.

Innovation Indicators: Patents

Patent filings are another indicator of the state of innovation in an industry. Patents are one visible output from the innovation process. Like the other indicators we use, patent filings are subject to a variety of biases. Sheer spending on innovation can raise patent numbers even without an increase in innovation levels because organizations need to demonstrate tangible outputs. Patents also vary in their importance. Finally, overall patent numbers have been rising as more industrial sectors try to emulate IP strategies long evident in pharmaceuticals and IT (where patenting is extensive). Nonetheless, patent data provide a useful tool to compare innovation patterns across time, sector, and geography.

FIGURE 8.

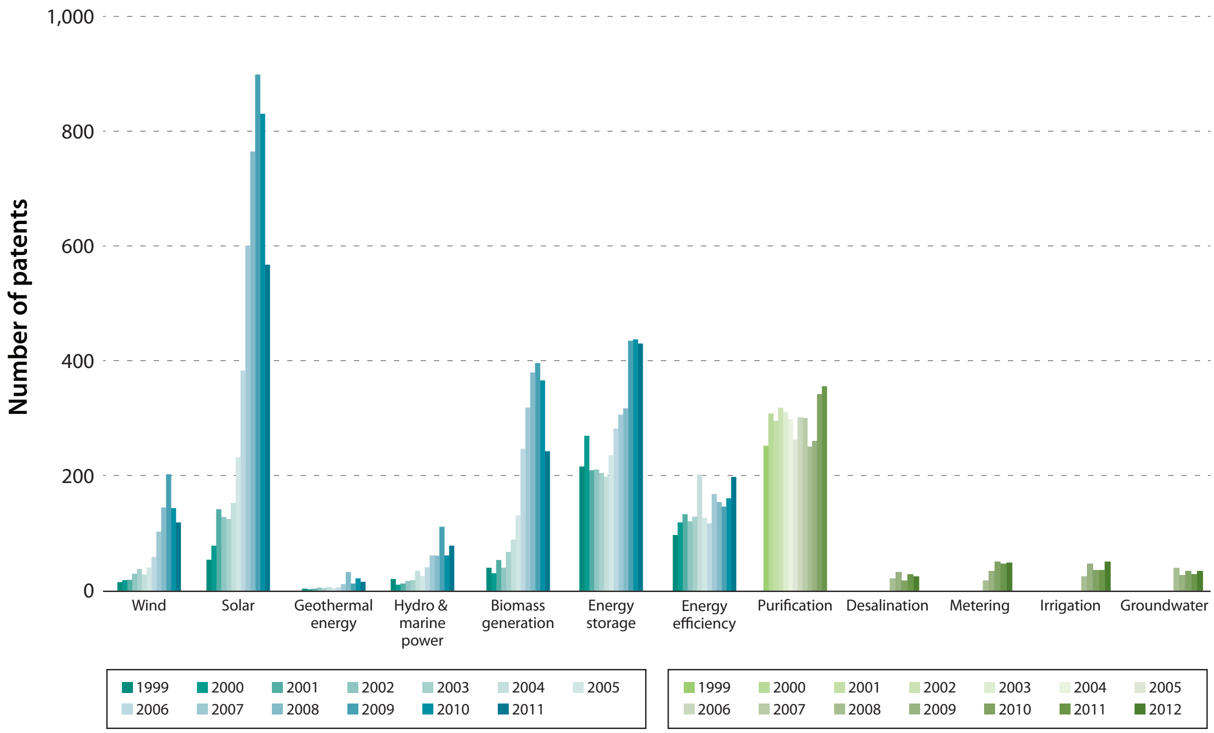
Patent Filings with Patent Cooperation Treaty for Water Purification and Clean Energy by Country, 1999–2011



Source: Organisation for Economic Co-operation and Development 2014.

FIGURE 9.

Number of U.S. Patents Filed in the Clean Energy and Water Subsectors, 1999–2012



Sources: Organisation of Economic Co-operation and Development (OECD) 2014; Foley and Lardner LLP 2012.

Note: Clean energy patent data (in blue) are filed with the Patent Cooperation Treaty and obtained from OECD (2014). Water subsector data (in green) are filed with the U.S. Patent and Trademark Office in the U.S. Department of Commerce. Water purification data for 1999–2011 are obtained from OECD (2014); water desalination, metering, irrigation, and groundwater data for 2008–2012 are obtained from Foley and Lardner LLP (2012).

The number of clean energy patent applications (renewable and nonfossil fuels) submitted annually increased dramatically during the 2000s, particularly in the European Union, Japan, and the United States (figure 8b). By contrast, the annual number of water purification patent applications filed in these countries has remained relatively constant (figure 8a). This is also true for the global pattern. Although figure 8a presents patents for water purification only, this subsector accounts for the majority of all water patents (figure 9).

Patent activity for the clean energy and water subsectors (figure 9) helps elucidate which technologies are driving the most innovation. The number of patent applications in solar technology has been the most prolific for the past decade, which is also reflective of the market size for this technology (figure 7). But patent activity is also substantial for a number of other clean energy subsectors, including energy storage and biomass generation. Patent activity in the water sector is much less evenly distributed. The number of patent filings for water purification technologies dominates. Desalination, metering, irrigation, and groundwater collectively contributed fewer than half as many patent applications in 2012. Though annual patent filings for purification have been growing, patent activity in the other water subsectors appears to be relatively stagnant. None of the water subsectors has achieved the acceleration in patent filings exhibited by most of the clean energy subsectors.

Innovative technologies do not necessarily have to be adopted by a regulated utility or SOE to attract funding. This is true for both the water and the energy sectors. The patent trends observed throughout this section highlight the importance of end-use or target markets. In general, innovative solutions such as purification technologies that cater to an industry, especially industries with high growth rates such as food and beverages, pharmaceuticals, and oil and gas, have attracted more funding and investment sources and seen a growing number of patent applications.

Chapter 4: Explaining Patterns of Innovation

Traditionally, change in the water sector has been reactive, often driven by operational necessity; natural disasters such as floods, fires, and droughts; economic realities; environmental regulations; and technological advancement in other sectors such as energy (Forer and Staub 2013). This often has led to adoption of less-innovative, mostly off-the-shelf and established solutions. Here we examine some of the barriers to current and future innovation in the water sector.

Some factors cannot be addressed by new government policies. Innate conservatism in the water industry is one such factor that hinders fundamental innovation. The fundamental importance of water to life and to all sectors of the economy, combined with the potential for water impurities to lead to illness and even death, means that public health concerns often trump virtually any other consideration, including cost. More than perhaps any other sector, water suppliers are reticent to use new technologies that have not been carefully tested at multiple scales and found to present no risk to the safety of water supplies.

As noted earlier, fragmentation of the water industry also poses an obstacle to the development and adoption of new technologies. Water suppliers in many parts of the United States are relatively small, making it more difficult for them to evaluate, test, or afford new technologies (Roy et al. 2008). The fragmentation of water supply also slows the diffusion of new technologies through the industry.[4] Fragmentation also can separate costs and gains. For example, adoption of recycling, desalination, or other technologies designed to produce additional water might benefit a region as a whole by diversifying its water supply, but pose a cost only to the local supplier (Kiparsky et al. 2013).

Water systems, for both freshwater delivery and wastewater disposal, are generally complex engineered systems, consisting of large-scale infrastructure (dams, reservoirs, aqueducts, pipelines, and treatment facilities) with long lifetimes. This infrastructure lasts for decades or longer, and has biased the water industry toward the adoption of incremental upgrades rather than toward more-innovative and groundbreaking technologies. The large-scale delivery of recycled water in developed areas, for example, requires new underground piping systems, which can be prohibitively expensive and disruptive to install when not done in connection with the replacement of existing piping systems. Yet most piping systems can last fifty years or longer. Even when individual elements of a water system need replacement, the rest of the system remains functional, making it more likely that the owner will simply replace the worn element rather than fundamentally rethink or replace the water system as a whole. New technologies, moreover, might not meet the engineering standards of the existing system. Finally, the expense and long lives of water systems generate sizable, long-term debt, which further commits organizations to existing technologies.

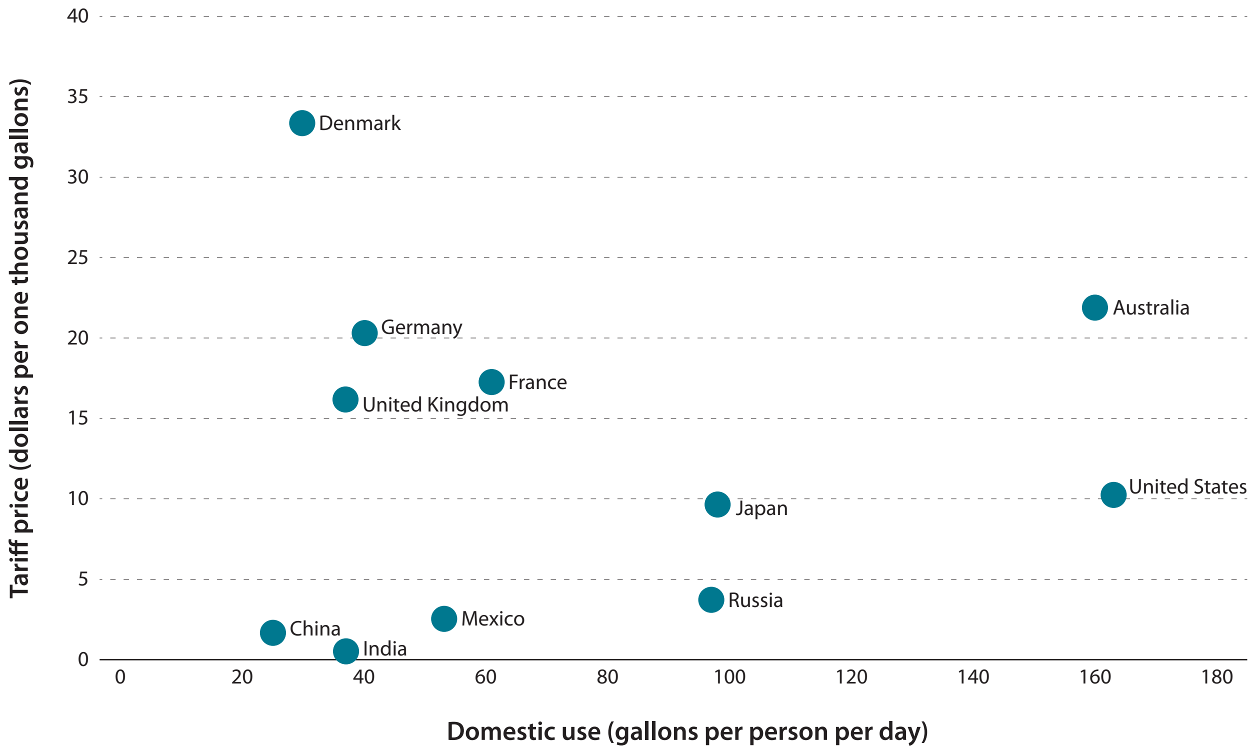
These factors—a risk-averse, conservative business climate; the typically long life expectancy, size, and complexity of water systems; and water systems fragmented by geography and function—help explain the lack of innovation in the water sector, but are not readily addressed by policy reforms. We therefore focus our policy proposals on three additional challenges that inhibit innovation, but that can be addressed through improved public policies—current water pricing practices, regulations, and lack of access to capital.

PRICING PRACTICES

The pricing of water presents a significant obstacle to innovation in the water sector. Water in the United States is generally underpriced and does not reflect the true economic cost of water to society. Many water systems subsidize the cost of extracting, conveying, purifying, and distributing water. Water suppliers also do not always charge prices adequate to replace their infrastructure as it ages. Finally, water prices never reflect the opportunity cost of the water supplied or the environmental externalities involved in furnishing the water. The extraction of water from surface waterways inevitably has a cost—in reduced recreational opportunities, harm to fish, or other physical or biological harm. Pumping of groundwater also can impact the environment, and over-pumping can cause subsidence and increase energy use. Water prices, however, do not reflect these costs. While water rates in the United States have been rising in recent years (Global Water Intelligence 2012), the average cost of water in the United States is still one of the lowest compared to other developed countries (figure 10; Forer and Staub 2013).

FIGURE 10.

Tariff Price and Domestic Use per Capita, 2012



Source: Standard & Poor's 2012.

Note: The tariff price includes water and wastewater tariffs and it is the average price among cities in that country.

The pricing of water in the United States affects innovation in several ways. First, it reduces the revenue available to water suppliers to invest in innovation. The ratio of capital investment to collected revenue for water supplies compared to other utilities in the United States (figure 11) illustrates how underpriced water is in this country considering its capital intensity. This often leads to a gap between revenue collected from customers and the total costs to operate these systems, leaving limited options to pursue innovation.

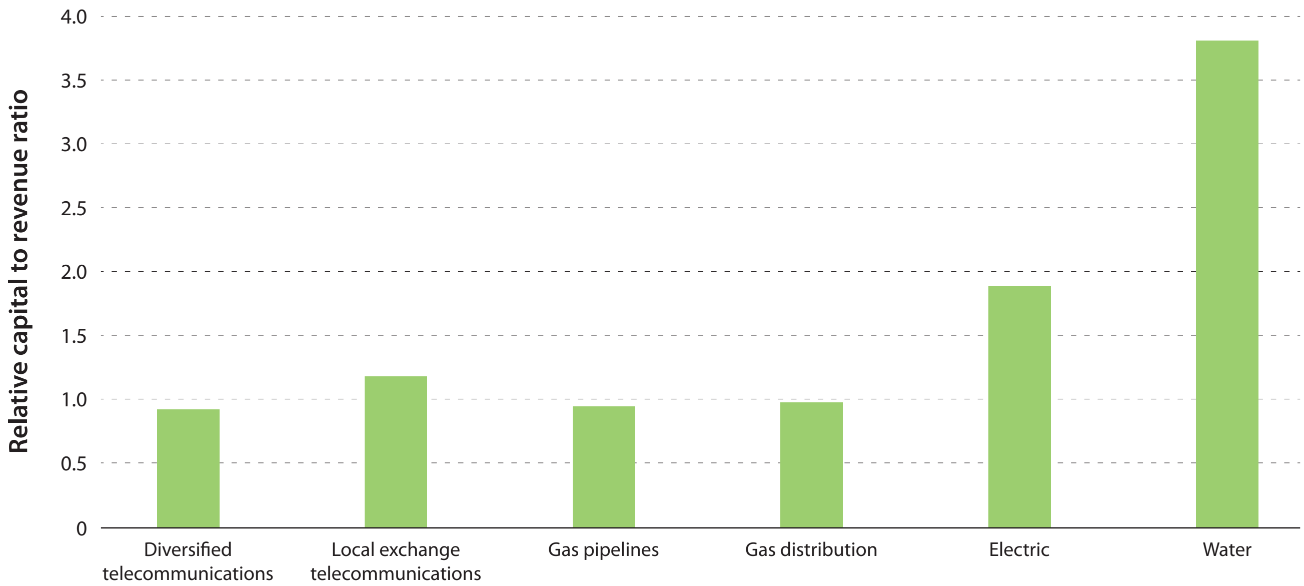
Inadequate pricing can create a vicious cycle where water suppliers are unable to replace existing infrastructure, which can further reduce their revenues. According to the EPA (2013), about 16 percent of the treated water in the United States is lost to leaky pipes and system inefficiencies. This translates to 7 billion gallons of clean water per day that is produced without generating any revenue for the water service providers (Maxwell 2013). Metering inaccuracies and unauthorized consumption also leads to revenue loss. Overall, about 30 percent of the water in the United States falls under the category of nonrevenue water, meaning water that has been extracted, treated, and distributed, but that has never generated any revenue because it has been lost to leaks, metering inaccuracies, or the like (Haji and Yolles 2013). This loss of revenue further jeopardizes recovery of the cost of service. These combined factors have led to shrinking capital and funding sources for future water projects, restraining access to capital and increasing the cost of financing new infrastructure (Ajami et al. 2012; Donnelly, Christian-Smith, and Cooley 2013).

Second, the underpricing of water can bias the decisions of water managers on whether to invest in innovative technologies. For example, as noted earlier the extraction of water from a river or stream can have significant environmental costs. Because prices do not reflect such costs, however, analyses to decide whether to extract additional water for a growing city or to invest instead in water recycling and reuse, which might not impose the same environmental costs, may incorrectly suggest that water extraction is the better approach. The problem is much the same as the failure to account for the costs of carbon emissions in energy decisions.

Third, the underpricing of water can undercut incentives that water users would otherwise have to invest in new technologies to reduce water use. Further reducing incentives, some water suppliers in the United States still do not meter their water. Those that do meter their water engage in average-cost pricing, where all water users in their jurisdiction pay the same price for each unit of water. New users therefore do not confront the

FIGURE 11.

Relative Capital Investment to Revenue Ratio for Several Utility Services



Source: Global Water Intelligence 2010.

full marginal cost of the water that must be brought into the region to meet their needs, further undermining incentives for users to invest in water-efficiency technologies.

The energy sector demonstrates the importance of full-cost pricing. Prices have had a huge impact on the adoption of renewable energy technology as well as technologies that are more energy efficient. States with the highest electricity costs—such as Hawaii and California—have seen the most active programs to advance wind, solar, and other forms of renewable electricity. Prices alone have not been sufficient to encourage massive investment, but prices in combination with policy supports have had a large impact. Given the higher prices, the size of needed regulatory and subsidy programs also have been more manageable politically. Some analysts now see even residential solar systems—among the more expensive forms of renewable power—becoming cost effective in Hawaii and California without policy support in the next few years (Byrd et al. 2014). High prices along with policy programs also have encouraged conservation and efficiency—which helps to explain why California's per capita electricity consumption has been flat since the early 1970s even as consumption in the rest of the nation has increased (Natural Resources Defense Council 2013).

REGULATIONS

Regulations can both help and hinder technological innovation. In both the energy and the water sectors, new regulations have often driven technological innovation. Regulations also can help reinforce existing technological change, encouraging broad diffusion of an innovative technology. Unfortunately, however, regulations can also serve as a barrier to innovation and lock organizations into existing technology. Table 1 presents a series of elucidatory examples that demonstrate how regulations can both facilitate and obstruct innovation in water recycling. The water regulatory drivers currently in use show the variety of approaches that governments can take to encourage the adoption of new water-recycling technology. No studies exist on the impact of these varied regulations on innovation in recycling, but they are likely to encourage innovation by (1) ensuring a significant market for recycling technology, (2) encouraging the diffusion of such technology, (3) enabling the refinement and improvement of recycling technology through actual use, and (4) driving the development of less-expensive recycling technologies.

Regulations can encourage innovation through different mechanisms. In some cases, regulations directly encourage the invention or adoption of new technologies that can meet the new regulatory requirements. In other cases, regulations can encourage innovation by banning or discouraging the use of existing technologies. Regulations that set performance standards that require new technologies (called technology-forcing regulations) will generally encourage greater innovation than regulations that simply require the use of a specific technology or general category of technologies (or technology mandates).

Perhaps the best example of technology-forcing regulation is the federal Clean Water Act. Under this Act, the EPA determines the best technology available, based on various technological and economic considerations that vary across types of point

TABLE 1.

Regulatory Drivers and Barriers to Adoption of Water-Recycling Innovations

Regulatory Drivers	Examples
Numerous jurisdictions require wastewater districts to examine opportunities for recycling or directly require types of water consumers to use recycled water.	Las Vegas, Nevada requires large-scale irrigators to use recycled water where available. Sydney, Australia requires new subdivisions to install dual piping systems that can deliver high volumes of recycled water.
Some governments force their offices to serve as early adopters of technological inventions.	California requires both its Department of General Services and its Department of Transportation to install pipes for recycled water in areas where recycled water will become available within a decade. Las Vegas, Nevada prohibits the use of potable water for artificial or created lakes.
Regulatory relief encourages the adoption of recycling technology.	In Austin, Texas city-adopted water conservation requirements do not apply to the use of recycled water. The City of Cerritos, California exempts irrigated landscaping from conservation requirements where recycled water is used. St. Petersburg, Florida exempts recycled water from drought restrictions.

Regulatory Barriers	Examples
Some jurisdictions ban recycling entirely without legitimate concern.	The California Department of Health Services bans the retrofitting of buildings for the use of recycled water.
More commonly, jurisdictions require costly permitting and inspection requirements, or impose expensive protective measures even in situations where the use of recycled water is clearly safe.	In California industrial plants that use recycled water must be inspected by the Department of Health Services, even though human contact with such water is remote to nonexistent. Taking an approach that is more favorable to the adoption of new recycling technology, Arizona requires state permits where recycled water is used on crops but not when it is used in industrial processes. California requires the use of dual pumping where recycled water is used in a building solely for toilet flushing.

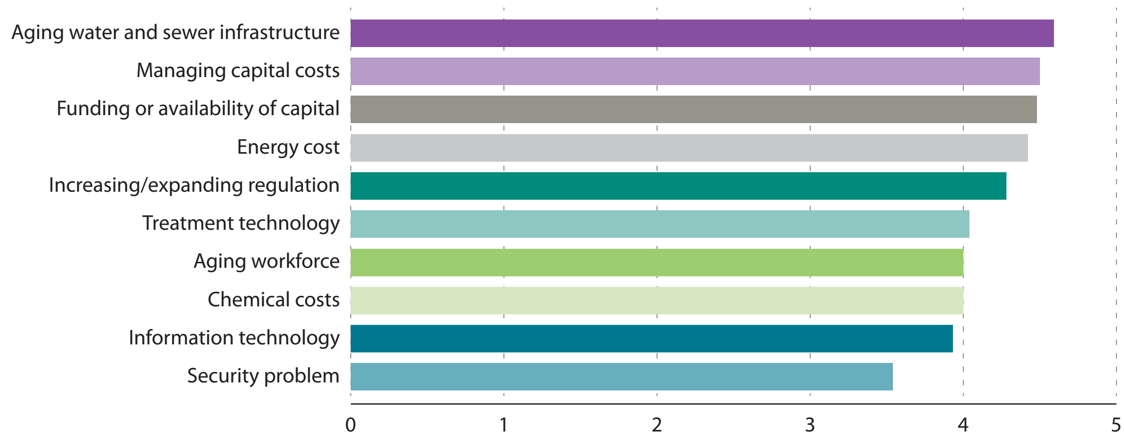
Source: Baker and McKenzie LLP 2008.

sources and pollutants. The EPA then requires companies to meet effluent standards based on this technology. Existing sources of water pollution, for example, must use the "best available technology economically achievable" (Federal Water Pollution Control Act 2002, p. 119, sec. 307), which is known as the BAT standard, to reduce toxic and nonconventional pollutants, or meet an effluent standard equivalent to what BAT technology would achieve. By imposing a BAT standard, the EPA encourages the development of better and more economically achievable technology. To ensure that the incentive continues over time, the EPA periodically reconsiders the BAT standard. By converting BAT technology into an effluent standard, rather than requiring that companies use the BAT technology itself, the federal government also provides companies with the flexibility of discovering other, even-less-expensive means of achieving the same result as the BAT technology—reducing the economic impact of the regulation and further encouraging new innovation, while not undermining effluent reductions.

Technology-forcing regulations have the ability to help drive down the cost of innovative technologies through shared experience and economies of scale. One study that tracked patenting related to scrubbers showed that the most aggressive

FIGURE 12.

Importance of Industry Issues, 2012



Source: Black and Veatch Corporation 2012.

Note: Survey participants were asked to rate the importance of each of the above referenced issues to the water industry based on a scale of 1 to 5, where 1 indicates "very unimportant" and 5 indicates "very important." The results above show the average response for each issue.

period of patenting came when regulated utilities were under technology-forcing regulations adopted by the EPA. During other periods, when incentives were market-based, firms engaged in less innovation (Taylor, Rubin, and Hounshell 2003).

Technology-forcing regulations are most effective when enacted in conjunction with other enabling actions, such as research support and information sharing. One of the best-studied examples—the sulfur dioxide control provisions of the 1990 Clean Air Act Amendments—demonstrated that sulfur dioxide provisions in conjunction with government research support encouraged innovation faster than did either measure by itself. Additionally, complementary technological conferences convened by the EPA helped promote knowledge diffusion, and thus the widespread adoption of new technologies.

The efficacy of regulation can depend on the industry and companies involved. Industries that are more mature and protected tend to resist change and often fight regulatory requirements that would require innovation. In response, governments often delay or soften initial regulatory standards. By contrast, smaller firms, as well as new entrants to a market, are generally more receptive to regulatory-driven innovation. One mechanism for dealing with the opposition of mature or protected industries is to provide for innovation waivers, in which the government waives technological standards in return for a company's commitment to develop and test new technological options.

Rate regulation by the Public Utility Commission also can affect the level of innovation by utilities. Although it has often been assumed that competition encourages innovation, some of the most highly regulated firms in the power sector are also the most innovative—in part because direct regulation allows them to manage the risks of innovation. During the most aggressive period of competition in the power supply industry, which began in the late 1990s, the incentives for marginal improvements in performance were very strong. But disruptive innovation, for the most part, has come from regulated or state-owned firms that can more readily absorb risk.

Applying this lesson to today's advanced coal technologies reveals what might be called the regulator's dilemma. The standard view is that regulated firms are not innovative, but that private, competitive firms are. But in power the main effect of creating the very market for those competitive firms has been to undercut innovation. That is exactly the pattern of investment that is evident today in advanced coal-fired power plants that use integrated gasification combined cycle and carbon capture and storage. These two processes are widely seen as critical to cutting emissions of carbon dioxide, the leading cause of global warming. As yet, however, essentially no power companies that operate as merchants in fully competitive markets—in contrast with utilities that are regulated as monopolies and thus have relatively assured customers, prices, and rates of return—invest in this technology. Within the United States the two power plants that are exploring these technologies—one in Indiana and one in Mississippi—are being built by regulated utilities that are passing most of the cost (and some of the cost overruns) on to customers with the blessing of regulators.

Regulation can, however, sometimes create a barrier to new innovation. Regulatory regimes often develop around existing technologies and may clash with the characteristics of new technologies. In some cases, manufacturers of existing technologies, or other vested interests, may use regulations as a market barrier. Even where regulations are justified, new technologies often face administrative costs stemming from the need for permits or other forms of regulatory approval that existing technologies do not face. Innovative technologies are novel by definition, and governmental officials addressing new technology without the benefit of experience can promulgate regulations that are at best redundant, and at worst inconsistent.

LACK OF ACCESS TO CAPITAL

For several reasons, the water sector is also facing challenges in its access to capital. Operation and maintenance costs are rising (Leurig 2012). At the same time, revenue is declining in response to reduced demand from conservation efforts and to leaks and inefficiencies in the water delivery system. These factors, in addition to inadequate pricing, have led to financial instability in the industry, jeopardizing the industry's credit quality and ultimately affecting its access to affordable capital. The lack of access to capital has introduced another barrier to seeking and embracing innovation. In a recent national survey done by Black and Veatch Corporation (2012), water service providers identified the availability of capital as one of the top three issues most important to the industry (figure 12).

The large role that the public sector plays in the water industry also inhibits the raising of capital. Unlike private companies, public entities such as cities and water districts rely on high-quality, low-yield bond funding. The accrued bond-related debt plus interest must be paid back out of generated revenue or from a locality's general fund. However, rising costs and declining revenue have jeopardized the market's evaluation of public water systems as low-risk investment, in some cases affecting their access to cheap capital and financing options (Forer and Staub 2013; Leurig 2012).

In addition, bond pricing and rating depend on the risks associated with a project. As a result, public entities often are unable to finance technologies that promise higher but riskier rates of return. For example, where the profitability of desalination technology depends on future water supply limitations and on future increases in the cost of other water-supply options, governmental entities may find it difficult to raise needed funding to build the desalination plant today (Kiparsky et al. 2013).

The financial stability and credit quality of a water organization are critical to capital availabilities. As one example, the West Basin Municipal Water District largely financed its innovative recycled water project, which provides recycled water in various qualities tailored to specific end-use (e.g., agricultural or industrial use), through the issuance of bonds and some federal and state grants (Lazarova et al. 2013). The water district would not have been able to access affordable capital (with a low interest rate) and finance the project if it had not demonstrated its good credit rating and stable cash flow projection (California State Auditor 2001). For the reasons discussed, many water utilities today are not able to obtain the same access to affordable capital unless they improve their financial standing.

Chapter 5: Infusing Innovation into the Water Sector

Although innovation is occurring throughout the U.S. water industry and throughout the water distribution and use cycles, it is incremental, fragmented, and focused primarily on water treatment and purification. Three sets of reforms are particularly important in order to promote increased water innovation. These reforms are proposed in light of the challenges, as laid out in "Explaining Patterns of Innovation" above, including the disconnect between the market price of water and the cost of supplying water, a regulatory framework that at times can hinder innovation, and a lack of public-sector financing for innovation. Our proposals are designed to overcome these barriers.

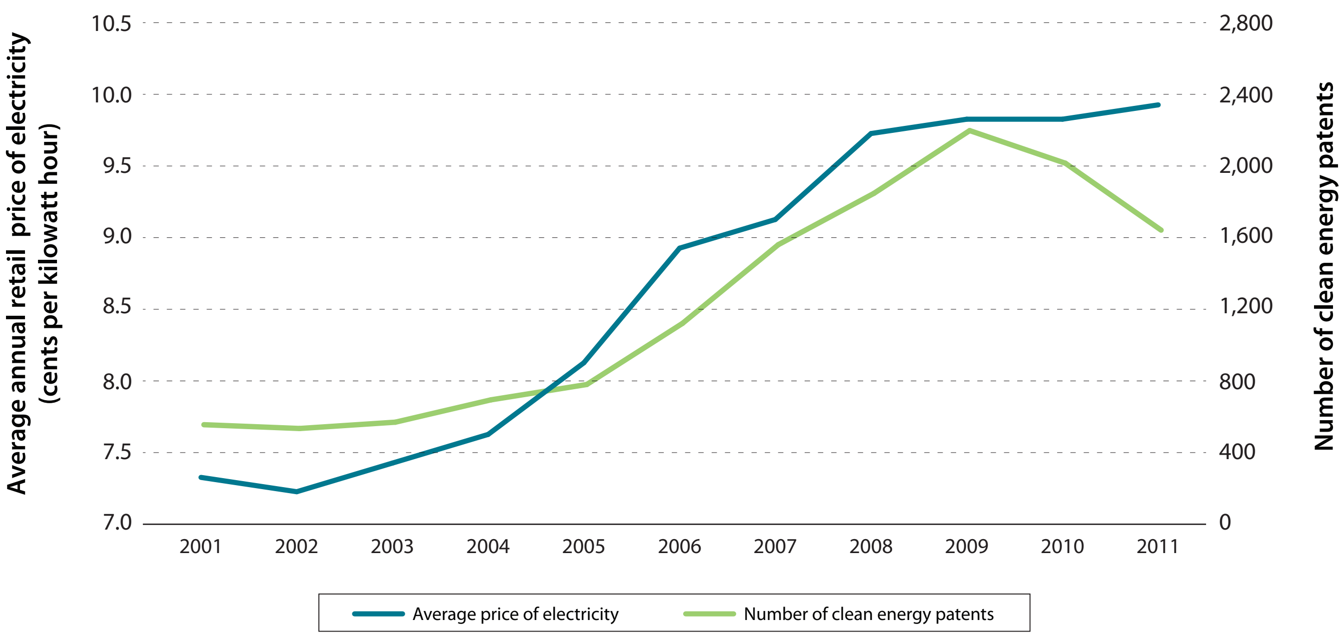
IMPROVE WATER PRICING POLICIES

We call for three targeted reforms to water pricing to strengthen innovation in the water sector. First, we advocate pricing schemes that capture the full cost of delivering water and that ensure the financial health of water suppliers. Second, we call for consumers of water to face the total marginal cost of each unit of water consumed, including any associated externalities. Finally, we propose that utility revenue be decoupled from the quantity of water sold, with rebates or surcharges compensating for any difference between projected and realized sales.

Rate reform in the water sector can play an important role in promoting new water technologies. Current pricing policies often fall short of capturing the full cost of water provision and wastewater treatment. Low water prices decrease the funding that water utilities have available to invest in innovation. They also undercut the economic incentives that water users have to invest in new conservation technology. Not surprisingly, studies have found that higher energy prices encourage greater investment by energy users in conservation technologies (e.g., Popp 2001). As shown in figure 13, electricity prices from 1999 to 2011 are strongly correlated with the number of clean energy patents issued.

FIGURE 13.

Number of Clean Energy Patents and Price of Electricity, 2001–11



Sources: Energy Information Administration 2014; Organisation for Economic Co-operation and Development 2014.

Water and wastewater utilities therefore should ensure full-cost pricing of their services. Water and wastewater rates should recover all the costs of the utilities' services, including the costs of replacing infrastructure over time and needed R&D. Consumers are accustomed to low water rates and frequently protest rate hikes (Apple Valley News 2014; Webb 2011). Nonetheless, it is important that water and wastewater utilities take steps in this direction. Absent rate reform, many utilities will remain financially incapable of evaluating, testing, and adopting new technologies.

Water utilities also should make water consumers confront the marginal cost of their water usage to give them an incentive to adopt efficient conservation technologies that can reduce that usage. Water utilities that charge flat fees for water, under which everyone pays the same price no matter how much water is used, should move to a metered pricing structure. Water utilities that charge a uniform unit rate to all consumers should move to a tiered (or block-rate) pricing structure that charges more per unit as overall consumption levels rise. Under tiered systems, consumers pay a reduced rate for a basic supply of water, but then face increasingly high rates as their overall consumption increases.

Many water utilities in the United States still charge uniform unit rates. In recent years, a growing number of water suppliers have adopted tiered systems. Successful tiered pricing structures apply to all water consumers, including industrial users; have low threshold consumption levels for the higher tiers; and charge sharply increasing rates for each succeeding tier. In 1990 the Irvine Ranch Water District in California became one of the first water suppliers to adopt a tiered rate structure. Irvine employs five tiers, and the cost per unit of water in the top tier, into which about 6 percent of consumers fall, is eight times the standard cost of the water in the lowest tier. Boulder, Colorado, adopted a tiered rate structure in 2007; under its system, the highest tier is five times the standard rate. In both regions, tiered pricing has encouraged consumers to invest in water-saving technologies. Not all water utilities, however, currently use tiered pricing systems. Moreover, those that do use them often have high volume thresholds for the higher tiers, so that few consumers fall into those tiers, or they have gently increasing tiers that fail to create effective conservation incentives.

Ideally, water rates also should reflect differences in the environmental and other impacts—or externalities—of various water supplies (Forer and Staub 2013). For example, as discussed earlier, extracting water from a river or lake frequently impacts fish and recreational opportunities. If the price of water does not reflect the cost of such externalities, water utilities will be less inclined to invest in new technologies, such as water recycling, that do not have such impacts. Yet states currently charge water utilities only a nominal fee, if any, for extracting water from a river or lake. As a result, water consumers pay for the operational and financial costs of the water they use, but not the environmental, recreational, and other opportunity costs. Since 1988 some European jurisdictions have imposed taxes on water extraction to reflect the accompanying externalities. These taxes both encourage water suppliers to look for alternative technologies and provide funding to support technological R&D.

> Water utilities should make water consumers confront the marginal cost of their water usage to give them an incentive to adopt efficient conservation technologies that can reduce that usage.

As in most industries, revenues in the water sector are the product of the price per unit and the sales volume. This coupling of water revenues to the volume of water sold can discourage investments in new technologies. Because water supply systems have high fixed costs, utilities can fail to earn enough revenue to recover their costs if water sales drop. The resulting revenue instability can raise the cost of capital and thereby deter investments in new technology. Because utilities have an incentive to sell as much water as possible (a

BOX 1.

California's Decoupling Experience

In 2006 California became the first state to try decoupling water rates (California Public Utility Commission 2008). California's pilot program applies to investor-owned utilities with more than 10,000 customers; together, these utilities furnish 95 percent of the water supplied by private companies in the state. Under the pilot program, utilities can use a water rate adjustment mechanism to recover revenues lost because of reduced sales from conservation or other causes. This mechanism reduces utilities' risk of falling revenue due to conservation, recession, or high precipitation and, as a result, both helps strengthen access to capital and lowers its cost.

phenomenon known as throughput incentive), they are also less likely to adopt or promote conservation technologies.

Water utilities can address this problem by "decoupling" their revenues from the quantity of water sold. Decoupling can be accomplished in several ways. Under the most common approach, utilities are guaranteed a target revenue based on expected sales and costs and use a true-up mechanism to periodically adjust their rates to ensure that actual revenue over time is equal to target revenue (Donnelly, Christitan-Smith, and Cooley 2013). Utilities therefore recover their target revenues regardless of actual sales. The regulatory body overseeing a utility sets the initial rate based on best estimates of sales and revenue. If sales turn out to be below the target, the utility is allowed to adjust its rates in the upcoming period to recover the lost revenue. If sales are above the target, the utility rebates the excess profits to its consumers through reduced rates. Under decoupling, water consumers still pay per unit of water used, thus encouraging them to conserve, but utilities enjoy more-stable revenues and are not dependent on expected sales.

Decoupling water rates promote new technologies in several ways:

- Water utilities no longer have an incentive to maximize the sale of water and therefore discourage the adoption of new conservation technologies.
- Water utilities have increased financial sustainability and therefore greater ability to invest in new technologies.
- Utilities have enhanced long-term access to capital.

In the energy sector, approximately half the states and the District of Columbia have decoupled rates for energy use (Robertson 2013). As predicted, when rates are decoupled, energy utilities generally enjoy greater financial stability and lower costs of capital. When used in combination with various conservation programs, decoupling also makes it more likely that utilities will invest in and encourage conservation technologies.

To date, however, only a handful of states, including Arizona, California, Connecticut, Nevada, and New York, have experimented with decoupled water rates (Wharton, Villadsen, and Bishop 2013). These experiments, moreover, have been limited to water rates charged by investor-owned utilities. In California, for example, the Public Utility Commission took the lead and ordered decoupled rates for the investor-owned utilities that it oversees (see box 1). As explained above, such investor-owned utilities furnish water to only about a fifth of domestic users in the United States.

There is no reason why public water suppliers cannot also decouple their rates. Decoupling in the energy sector also historically was limited to investor-owned utilities. Yet earlier this year two public electricity providers in California—the Los Angeles Department of Water and Power and Glendale Water and Power—decoupled their electricity rates. In both cases decoupling was accomplished through a mechanism very similar to that employed for investor-owned utilities; the only difference was that the city council, rather than the state utility commission, adopted and implemented the policy. Both utilities have reported that they are so pleased with the results that they are now considering decoupling their water rates as well (Xue 2014).

DEVELOP INNOVATION-FRIENDLY REGULATION

Regulation in the water sector can both promote and inhibit innovation. To ease the negative impact of regulations that restrain the water sector, we recommend a two-pronged approach to regulatory reform. First, we propose a statewide review of regulatory practices along several key criteria. Second, we propose that select states create offices of water innovation to better coordinate innovation efforts and recommend and oversee regulatory reforms to the state's water sector.

Regulations today can pose a major barrier to innovation. Regulations often have developed around existing technologies and may be insufficiently adaptive to new innovations. Regulations, moreover, are often fragmented geographically (with local regulations, e.g., sometimes blocking technologies that are permitted or even encouraged by state law) and by issue (with health and safety regulations, e.g., sometimes conflicting with water supply goals). In addition, unlike the technology-forcing incentives of the Clean Water Act, few state or other federal laws encourage new innovations in the production or delivery of water supplies or in the reduction of energy used in water systems.

We recommend that each state conduct a systematic review of its regulatory practices relating to the water sector. Each review should be conducted along the following parameters:

- State legislators and regulators should avoid geographically inconsistent regulations. New technologies can confront a baffling assortment of local regulations that are all too often inconsistent with each other. Where there is no need for local variation, states should set uniform statewide regulations. Such regulations should preempt inconsistent local regulations. States also should seek to coordinate their regulations with neighboring jurisdictions. Companies may be less likely to pursue innovation if they must meet different standards in every jurisdiction. Countries in the European Union have sought to adopt uniform rules that provide legal consistency and encourage the development and adoption of new technologies.

- Legislators and regulators also should consider cross-sector impacts when adopting new regulations. Wherever possible, new rules should coordinate across sectors (e.g., water and wastewater, or water and energy) to ensure consistent treatment of new technologies and reduce unnecessary obstacles. Regulation, in short, should provide for cross-sectoral consistency.

- State regulations should provide sufficient flexibility to avoid blocking the timely adoption of new and innovative technologies. In particular, regulations where possible should be based on performance, rather than on the adoption of particular technologies or on the meeting of specific criteria that are technology-specific and not needed to ensure the achievement of the ultimate performance goals.

- State legislators and regulators should consider the appropriateness of rules that encourage the adoption of new technologies. Renewable energy technologies have benefitted from technology-forcing regulations and goals, such as renewable performance standards that require utilities to furnish a specific percentage of their electricity through renewable technologies. Some states and local jurisdictions have similarly encouraged the adoption of recycling technology by requiring recycled water to be used in certain circumstances (or similarly banning the use of freshwater extracted directly from rivers or lakes). Other states have encouraged the use of new technologies by requiring water and wastewater utilities to evaluate the potential adoption of such technologies.

The goal of the review would be the development of recommendations for needed regulatory changes, whether new regulations or the elimination or modification of existing regulations. This study could be conducted by the principal state water agency or by an interagency review team.

Once existing regulations have been reviewed and revised, legislators and regulatory agencies should ensure that future regulatory actions are consistent with technological innovation. Before adopting new regulations, key decision makers should investigate what technologies might be affected and whether any resulting deterrence is justified. Once again, states' existing water agencies should assist in such preregulatory reviews.

A second prong of our proposed regulatory reform calls for some states to establish an office of water resources innovation and development (that we will call an innovation office), tasked both with developing a vision for the role of technological and managerial innovation in driving sustainable water resource management and with promoting policies to implement that vision. A major area of focus would be regulatory support. Ultimately, all states may wish to establish such offices. However, initially those states with the greatest opportunities and interest could take the lead.

The process for evaluating and creating such an office will vary from state to state depending on each state's existing water governance system. Under one approach the legislature or governor could first create an independent commission or task force comprising policymakers, academic experts, and major stakeholders to undertake a series of studies examining various water challenges and opportunities in the state, auditing the overall state of innovation in the water sector, and identifying innovative solutions to address some of the existing challenges. The independent commission or taskforce then could draft a water innovation vision and plan for the state. While a major component of the innovation plan would be recommendations on how to overcome regulatory fragmentation and establish a regulatory framework that promotes and enables innovation, the plan also could address other obstacles to technological innovation, including pricing policies and financial challenges. The legislature or governor then could decide if implementation of the vision requires a new guiding body such as an innovation office that could work across agencies and geographic scales, or if an existing office within the principal water agency or a related agency can implement the plan.

The state innovation office could have multiple functions. The office could be primarily tasked to promote recommendations of the commission or task force and a regulatory environment that is supportive of technological innovation, or it could be tasked to overcome institutional, sectoral, and financial fragmentation and promote systematic within-sector and cross-sector coordination on technological advances. More generally, the innovation office, working closely with regulatory bodies at various governmental levels, could be responsible for:

- Examining the continuing role of innovation in promoting sustainable water management;
- Coordinating and streamlining laws and regulatory frameworks in order to promote and not hinder technological innovation;
- Identifying and promoting best management practices, including appropriate pricing policies, for promoting innovation;
- Collecting and publishing relevant water resources data, which are essential to effective evaluation of new water technologies;
- Acting as a clearinghouse for all funding sources and identifying and enabling access to nongovernmental funding sources;
- Encouraging and facilitating cooperative funding and development of new technologies among multiple water entities, by, in-part, expanding public–private partnerships; and
- Promoting coordination on new technologies among and within sectors (e.g., between water and wastewater agencies, and between water and energy sectors), as well as across all relevant jurisdictional levels (local to state to federal).

The innovation office also could be given the authority to promote the development, testing, and adoption of new technologies. It could work with water suppliers, for example, to develop consortia to jointly fund and conduct the testing of new technologies at scale. Such consortiums could help achieve economies of scale that are often missing in areas where water suppliers are highly fragmented; the consortiums also could help overcome geographic mismatches in benefits and costs. One model for these consortia is the Electric Power Research Institute (EPRI). In the aftermath of the large blackout of 1965 (and other noticeable failures of the power sector), the industry knew that it faced tougher regulation by the federal government if it did not act to address collective challenges. The response, in the early 1970s, was the creation of EPRI—now the world's premier collective R&D institution for the power sector.[5] Although EPRI is an industry-led research consortium, it is tightly linked in practice to the regulatory system since regulatory approval for R&D costs and regulatory incentives for adoption are critical. The innovation office also could have responsibility to disseminate information about the performance and costs of new technologies to other water suppliers, in order to encourage appropriate diffusion of effective technologies.

Regional socioeconomic realities and climatological and hydrological variability have created a wide range of issues that require different sets of solutions. Since the challenges that the water sector faces vary dramatically across the country, innovation offices can be customized to handle the specific set of challenges arising in their respective states. Consequently, the scope and focus of the innovation office would differ to address various fronts, such as water-quality degradation, water scarcity, aging infrastructure, flooding, and so forth. Additionally, it would be ineffective, at least initially, for all states to adopt their own innovation offices. The largest states with the greatest water challenges—California, Texas, Florida, or a consortium of like-challenged states such as those in the West—are well-positioned to take the lead. Other states could follow, formulating their offices based on the lessons learned from the first innovation offices.

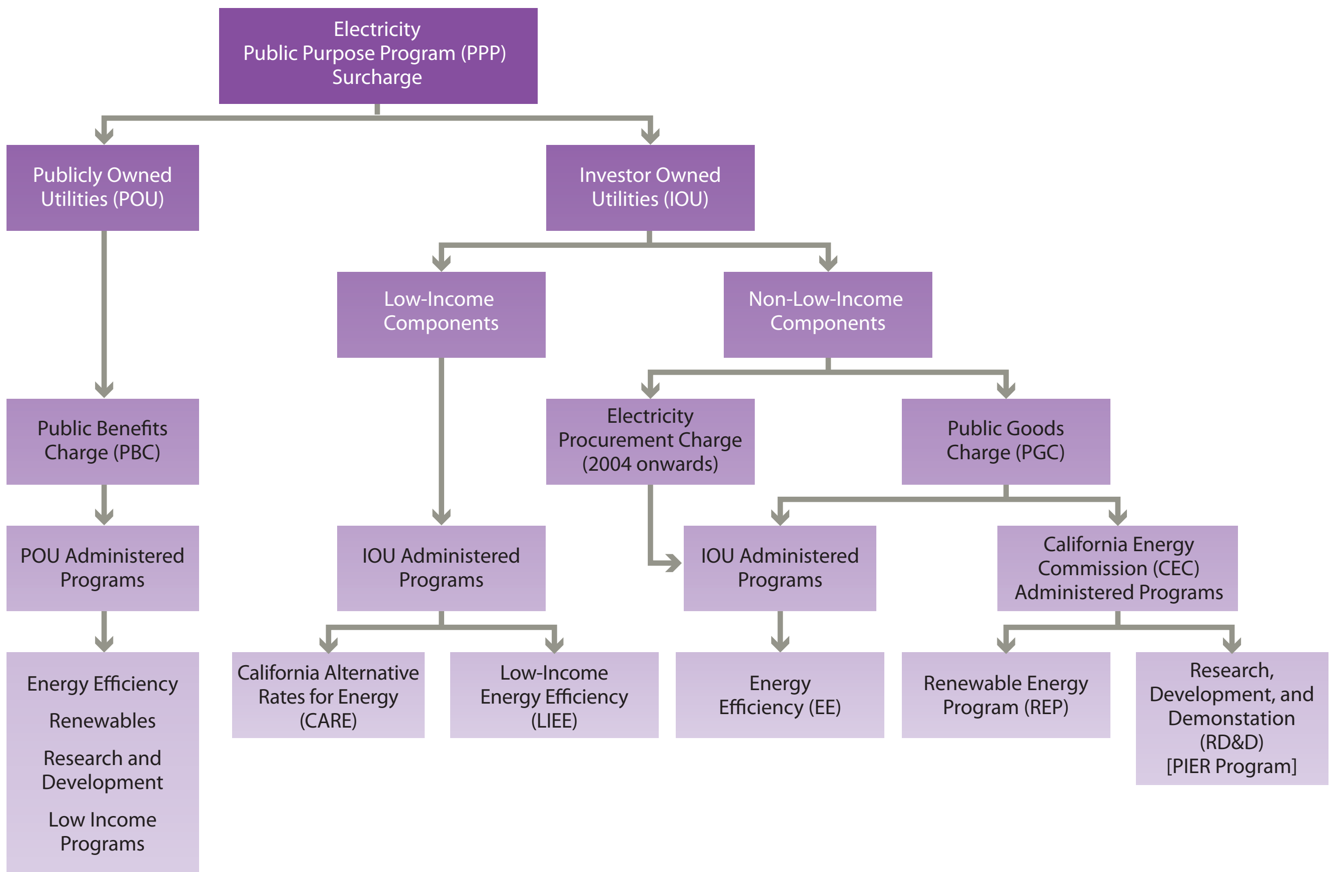
Furthermore, the federal government can play a supportive role to the innovation offices, especially for states that lack the expertise or funding to promote innovation on their own. Through the EPA, the federal government could supply expertise and enable information sharing of best practices among the states. It could reward best practices with race-to-the-top funds and a periodic innovation report card. It could also engage public utility regulators such as the nonprofit National Association of Regulatory Utility Commissioners (NARUC) to promote adoption of innovation-driving regulations. NARUC could also play a separate but central role in evaluating the performance of these innovation offices and could disseminate the lessons to other states—just as NARUC does in key areas of electricity and gas regulation.

INSTITUTE A MECHANISM FOR RAISING PUBLIC FUNDS FOR INNOVATION

In order to create a stable and sustainable source of funding to finance implementation of innovative projects, we recommend that authorities institute a surcharge on water usage, or public benefit charge (PBC). The surcharge would create a pool of monies that could be used to invest in R&D, reduce the cost of new technologies, and attract private capital. State legislators, regulators, and local entities would need to work out the set-up and governance of a PBC for each state. The PBC could be collected and run by local water utilities, or it could be administered and distributed directly by a statewide entity such as the water innovation offices discussed in the last section. Either way, the state should provide clear guidance on how the money should be invested and leveraged to attract the maximum amount of capital.

FIGURE 14.

Governance Structure of Public Good Charge for Electricity in California



Financing and funding mechanisms play a central role in the development and adaptation of innovative solutions by the water sector (EPA 2014). Across the United States urban water systems are gradually reaching the end of their life span. In the coming decades communities will need access to sustainable and reliable sources of financing to replace degraded infrastructure, expand existing water systems, and mitigate the impacts of climate change (Forer and Staub 2013). The water sector should explore new and innovative financing mechanisms and investment strategies, in parallel to pricing and regulation reform, to meet necessary urban water needs. Improved finance is needed both for investment in the core water system and for innovation itself. The former requires aligning the incentives for investors. The latter requires addressing, head on, the reality that many of the benefits of fundamental innovation are a public good. Better pricing will to a large degree address these challenges.

The federal government can play a supportive role in financing and funding the development of innovative solutions. In particular, the federal government often plays the role of catalyst through funding R&D and providing low-interest loans and grants to pilot and implement innovative projects. The recent establishment of the Water Infrastructure Finance and Innovation Authority (WIFIA), as part of the Water Resources Reform and Development Act of 2014, is a demonstration of the federal government's potential role. WIFIA, a five-year pilot program, offers a financing mechanism to leverage public funds to attract additional private and public (nonfederal) monies and facilitate development and implementation of critical water infrastructure. Such efforts by the federal government in conjunction with other local public and private financing mechanisms including the PBC could facilitate a faster rate of innovation in the water sector.

Figure 14 depicts the governance structure of California's electricity Public Good Charge program, which was active for fourteen years (1998–2011) and provides one model for a PBC in the water sector. California's legislature established the Public Good Charge program to support investments in energy efficiency, renewable energy (including new renewable facilities, emerging renewables, existing renewables, consumer education, and customer credit), and public interest R&D. The California Solar Initiative illustrates how California's Public Good Charge promoted innovation. The Initiative's aim was to reduce the cost of new solar technologies while not excessively subsidizing firms and individuals that adopted the technologies. The subsidies were funded through the monies collected as part of the Public Good Charge program in California. Implemented in stages (the final stage occurred in June 2014), subsidies started at a high level and then declined—broadly in line with the improvement in solar technology. Because the schedule for subsidies was announced far in advance, the California Solar Initiative created an incentive for early adopters and helped to accelerate the widespread use of rooftop solar power in the state (California Public Utilities Commission 2014). This approach of setting declining subsidies with performance is widely used—for example with the feed-in tariff in Germany and the sugar ethanol program in Brazil (see Victor 2011, chap. 6).

Another example of how a PBC can promote innovation is the water stewardship rate of the Metropolitan Water District of Southern California (MWD). In 2002 the MWD added a fixed charge on its water rates to fund its Conservation Credits Program, a program that provides financial support for conservation programs within MWD member agencies (MWD 2001); funds rebate programs; and supports R&D, education, and outreach efforts. The funds have also been used to encourage the deployment of water supply enhancement projects in the region.

A PBC addresses the water sector's fundamental challenge of raising sufficient revenue for innovation given its public-sector nature. For the 80 percent of the water market that is supplied through SOEs, a public surcharge on water users is perhaps the most economically efficient mechanism for raising new capital while most closely tying the cost to the users of water. Ultimately, the goal of the PBC is to reverse the long-standing trend of exceptionally low public investment in water innovation.

Chapter 6: Conclusion

The U.S. water sector, while the largest in the world, has been slow to promote, adopt, and implement new technological innovations. The water sector has largely taken a reactive and conservative approach to innovation. Multiple factors have driven the low level of innovation, including unrealistically low water rates, regulatory limitations, lack of access to capital, concerns about public health and possible risks associated with innovation, the conservative culture of the industry, and the long life expectancy, size, and complexity of most water systems. Although the last three factors are largely endemic to the water sector, new policies addressing the pricing, financing, and regulation of water can make the sector more receptive to innovation.

Comparatively robust innovation rates in the clean energy sector highlight the slow innovation rate in the water industry. Venture capital and corporate capital investments are significantly lower in the water sector than they are in the clean energy sector both in the United States and globally. Low flows of cash into the water industry have also affected the number of patent filings in this sector compared to the clean energy sector.

Our analysis shows that most of the barriers to innovation are related to the way we govern water. The goal should be to create an open and flexible environment that is innovation friendly. In this paper we put forward three recommendations that we believe are key to moving the water sector forward. We believe that pricing policies, regulatory frameworks, and financing and funding mechanisms are the top issues that have to be addressed in the water sector. Therefore we have offered specific recommendations explaining how each of these policy and governance factors can be revised and reformed in order to facilitate greater innovation. Furthermore, we recommend that each state draft a water innovation vision that would identify the state's challenges and opportunity areas. The vision can be implemented through the establishment of an innovation office. More specifically, the office would work with local governments, water authorities, and other relevant sectors to promote a series of best management practices related to pricing policies, to streamline regulations across and within sectors, and to enable access to funding.

Chapter 7: Questions and Concerns

How can states and local agencies be encouraged or incentivized to implement the proposed reforms?

Climate change, growing populations, and aging infrastructure all pose serious challenges to water suppliers. Water managers will find it difficult to meet these challenges without new technologies that permit them to do more with less water and at a lower cost. States and local water agencies therefore are likely to be supportive of measures that will ensure more-innovation-friendly regulation and access to affordable capital; they may be less receptive to price reforms due to concerns of consumer backlash. Jurisdictions are most likely to adopt these reforms when they are in the midst of a serious drought or otherwise face a significant water shortage.

Although state and local governments may naturally support many of the reforms that we suggest, the federal government also can play an important role in encouraging and incentivizing the reforms. First, both the Environmental Protection Agency (EPA) and the Department of the Interior can help educate state and local governments on the opportunities for reform and provide case studies of successful reform efforts. Second, federal agencies can use existing programs and policies, such as Interior's WaterSMART program and EPA's Clean Water and Drinking Water Infrastructure Sustainability Policy, to provide technical and financial assistance to states and local governments who wish to adopt innovation-friendly pricing systems, ensure that their regulations are supportive of innovation, adopt new financing mechanisms, or create water innovation offices.

Would states need to build additional capacity or provide additional funding for these reforms?

Most of the reforms presented in this paper, including reforms to pricing, regulations, and public financing, do not require significant new capacity or funding from state governments. The only reform that could require additional capacity or funding is the establishment of an innovation office. A task force or commission in each state would initially evaluate the steps needed to promote innovation, including the potential value of an innovation office. As part of this evaluation, the task force would examine the capacity needs of such an office and how the office might be financed. The exact needs of an office would depend on its mandate and activities. In some cases, a state might be able to create the office without a significant investment of new resources by reallocating resources within an existing state agency.

If the innovation office would need new resources, the state may be able to fund the office and related activities either by allocating a portion of the funds collected from the public benefit charge or through funding from the local water agencies who would benefit from the office. States could require local agencies to fund the office, or they could institute a membership model under which local agencies could voluntarily decide whether to provide funding. In the energy sector, the Electric Power Research Institute (EPRI) successfully relies on voluntary subscriptions to support its activities. Like the Institute, a state innovation office could open its membership not only to local water agencies, but also to businesses and other governmental agencies interested in promoting innovative water technologies. EPRI estimates that, by pooling the resources of its members, it provides them with ten dollars in research and development for every one dollar received in contributions. Under this model, members would presumably receive benefits, such as the ability to formulate research goals and access research results, that are not available to nonmembers. However, other activities, such as regulatory reform, would benefit all water agencies.

Should there be a mandate for these pricing reforms?

In many cases, state or federal mandates may not be necessary. Water suppliers will often want to develop larger and more-reliable revenue streams in order to respond to the multiple water challenges facing them. Moreover, some reforms, such as decoupling revenue from the quantity of water sales, may not increase water consumers' rates and therefore not engender significant political opposition. Other reforms, such as full-cost pricing and tiered pricing schemes, may threaten consumers' budgets and therefore attract political opposition. Many water suppliers, nonetheless, have successfully raised rates or reformed their pricing structures. Education of customers has often been the key to success in these cases. Consumers are much more likely to accept higher rates if they understand the necessity of the rate increase or the benefits of reform.

Both the state and federal governments, moreover, can help encourage pricing reforms without resorting to mandates. First, these governments can provide information and programs designed to help water suppliers explain the necessity of the reforms to their customers. Second, where state governments require water suppliers to adopt efficiency or conservation policies, the states can make pricing reforms such as those recommended above meet the requirements. The pricing reforms not only would help promote innovation, but would also encourage conservation and more-efficient water use.

Where pricing reforms prove impossible, water suppliers or states might be able to adopt other policies that mimic the effect of the reforms but with less political opposition. For example, if a water supplier is unable to raise its rates because of consumer opposition, the supplier might use a shadow price (i.e., a price equal to the full cost of the supplier's water, including environmental and other costs) to determine what investments to make in new technology. Innovation opportunities that may be cost-ineffective when based on actual water rates could actually be cost-effective when shadow prices are used instead.

What will be the potential obstacles or resistance to these reforms?

There are three major obstacles or sources of resistance.

- **Salience.** The first obstacle is likely to be the low salience of water issues in normal water years. Most politicians pay little attention to water issues, except in times of drought or other crises. Water utilities are often risk-averse organizations, and water managers attract attention and lose their jobs only when they err or anger customers. As a result, the focus is on inaction rather than action. Because of this obstacle, advocates of more-innovative and more-effective water systems must be ready to push for reforms during periods of drought and other crises. Advocates must also document the serious problems that are likely to go unsolved in the future if innovation is not promoted.

- **Financial Impacts.** Water consumers are often likely to oppose reform measures that will result in higher water prices. States and other governments also are likely to oppose reform measures that will require scarce governmental funding and resources. Despite such opposition, however, pricing reforms have taken place in many states and local jurisdictions. Many of our suggested reforms can be undertaken with little, if any, additional resources from state or local budgets.

- **Complexity.** Even as awareness of the importance of innovation increases, meaningful reforms can often seem daunting because they implicate so many different actors and involve so many diverse organizational changes, including changes in culture. Therefore, not all the proposed reforms will be adopted and implemented overnight. The federal government can help by developing case studies of successful reform efforts and providing states with the guidance needed to address the complexity of the reforms.

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Endnotes

1. Evapotranspiration is the loss of water to the atmosphere both by evaporation from the soil surface and by transpiration from the plants growing on it.
2. Two large SOEs in the energy sector—the Tennessee Valley Authority and Bonneville Power Authority—are major exceptions.
3. Comparisons between the sectors are hard to make with precision because technologies do not fit in neat boxes. For the purpose of this paper, the term "clean energy" encompasses renewable and non-fossil-fuel-derived energy, and energy efficiency. Unless otherwise indicated, clean energy includes biomass generation, energy efficiency, energy storage, geothermal, hydro and marine power, nuclear, smart grid, solar, and wind.
4. In California alone, literally thousands of different entities—local governments, special districts, and privately owned water companies—manage and deliver water at the local level. Domestic users receive water from about 400 large retailers and several thousand smaller, typically rural, retailers. Hundreds of separate agricultural water districts provide water to the state's farming community (Hanak et al. 2011).
5. While most EPRI spending is focused in the United States, in some areas—such as nuclear power—the institution essentially spans the whole globe since the key lessons learned from R&D are global and the relevant funders of such work are increasingly outside the United States.

References

Ajami, Newsha, Peter Gleick, Kristina Donnelly, Matthew Heberger, and Ahmed Fikri. 2012. *Transformational Ideas to Enhance Water Security.* Oakland, CA: Pacific Institute for Studies in Development, Environment and Security.

Apple Valley News. 2014. "Town Files Protests to Water Rate Case." *Apple Valley* [CA] *News*, May 28.

Baker and McKenzie LLP. 2008. "Addressing Water Scarcity Through Recycling and Reuse: A Menu for Policymakers." Technical Paper, Water and Process Technologies, General Electric Company, Fairfield, CT.

Besant-Jones, John E. 2006. "Reforming Power Markets in Developing Countries: What Have We Learned?" Paper No. 19, The World Bank and Energy Mining Sector Board, Washington, DC.

Black and Veatch Corporation. 2012. "2012 Strategic Directions in the U.S. Water Utility Industry." Overland Park, KS.

Bloomberg, Michael R., Henry M. Paulson, and Thomas F. Steyer. 2014. "The Economic Risks of Climate Change in the United States." Risky Business. http://riskybusiness.org/uploads/files/RiskyBusiness_Report_WEB_7_22_14.pdf.

Byrd, Stephen, Timothy Radcliff, Simon Lee, Bobby Chada, Dominik Olszewski, Yuka Matayoshi, Parag Gupta, Miguel Rodrigues, Adam Jonas, Peter J. Mackey, Paul R. Walsh, Mary Curtis, Roy Campbell, and Dimple Gosai. 2014. "Solar Power and Energy Storage: Policy Factors vs. Improving Economics." Blue Paper, Morgan Stanley Research, Washington, DC.

California Public Utilities Commission. 2008. "Program and Achievements toward Water Conservation Goals, Public Utilities Code § 1714.5." California Public Utilities Commission, San Francisco.

———. 2014. "About the California Solar Initiative." California Public Utilities Commission, San Francisco.

California State Auditor. 2001. "Central Basin Municipal Water District: Its Poorly Planned Recycled-Water Project Has Burdened Taxpayers but May Be Moving toward Self-Sufficiency." California State Auditor, Sacramento.

Cayan, Daniel R., Tapash Dasa, David W. Pierce, Tim P. Barnetta, Mary Tyreea, and Alexander Gershunova. 2010. "Future Dryness in the Southwest U.S. and the Hydrology of the Early 21st Century Drought." *Proceedings of the National Academy of Sciences* 107 (50): 21271–76.

Cleantech Group. 2014. "i3 Quarterly Innovation Monitor: Water and Wastewater." Cleantech Group, San Francisco, London, New York. https://i3connect.com/front_page?ref=%2F.

The Climate Registry and Water Energy Innovations. 2013. "California's Water-Energy-Climate Nexus: Energy and Greenhouse Gas Emissions Embedded in Water." Climate Registry, Los Angeles.

Dai, Aiguo. 2010. "Drought under Global Warming: A Review." *Wiley Interdisciplinary Reviews: Climate Change* 2 (1): 45–65.

Donnelly, Kristina, Juliet Christian-Smith, and Heather Cooley. 2013. "Pricing Practices in the Electricity Sector to Promote Conservation and Efficiency." Pacific Institute, Oakland, CA.

Federal Water Pollution Control Act [As Amended through P.L. 107-303, November 27, 2002]. 2002. http://www.epw.senate.gov/water.pdf.

Foley & Lardner LLP. 2012. "Water Technology U.S. Patent Landscape Annual Report." Foley & Lardner LLP, Chicago. http://www.ip-watch.org/weblog/wp-content/uploads/2013/12/Water-Report-2013-Summary.pdf.

Forer, Giland, and Christine Staub. 2013. "The U.S. Water Sector on the Verge of Transformation." Global Cleantech Center white paper, Global Cleantech Center, San Francisco and New Delhi.

Global Water Intelligence. 2010. "Water Markets USA." Global Water Intelligence, Oxford.

———. 2011. "Global Water Markets 2011: Meeting the World's Water and Wastewater Needs until 2016." Media Analytics Ltd., Oxford.

———. 2012. "Tariff Rises Outstripped by Inflation." *Global Water Intelligence* 13 (9).

Haji, Sheeraz, and Peter Yolles. 2013. "Smart Water: Many Reasons to Lose But Some Will Win Big." Cleantech Group, San Francisco, London, New York. Webinar. http://info.cleantech.com/SmartWaterAug62013-Registration.html.

Hanak, Ellen, Jay Lund, Ariel Dinar, Brian Gray, Richard Howitt, Jeffrey Mount, Peter Moyle, and Barton "Buzz" Thompson. 2011. "Managing California's Water: From Conflict to Reconciliation." Public Policy Insitute of California, San Franscisco.

Hering, Janet G., T. David Waite, Richard G. Luthy, Jorg E. Drewes, and David L. Sedlak. 2013. "A Changing Framework for Urban Water Systems." *Environmental Science and Technology* 47 (19): 10721–26.

Heslop, Janelle, and Amanda Faulkner. 2013. "Accelerating and Sustaining the Water Innovation Ecosystem: What's Next?" Cleantech Group, San Francisco.

Kiparsky, Michael, David L. Sedlak, Barton H. Thompson Jr., and Bernhard Truffer. 2013. "The Innovation Deficit in Urban Water: The Need for an Integrated Perspective on Institutions, Organizations, and Technology." *Environmental Engineering Science* 30 (8): 395–408.

Lazarova, Valentina, Takashi Asano, Akica Bahri, and John Anderson, eds. 2013. *Milestones in Water Reuse: The Best Success Stories*. London: IWA Publishing.

Leurig, Sharlene. 2012. "Water Ripples: Expanding Risks for U.S. Water Providers." Ceres, Boston.

Maxwell, Steve. 2013. "Growing Awareness, Growing Risks." TechKNOWLEDGEy Strategic Group, Boulder, CO.

Metropolitan Water District of Southern California (MWD). 2001. "Annual Progress Report to the California State Legislature, Achievements in Conservation, Recycling and Groundwater Recharge." Metropolitan Water District of Southern California, Los Angeles.

National Research Council. 1999. *Funding a Revolution: Government Support for Computing Research*. Washington DC: The National Academies Press.

Nemet, Gregory F., and Daniel M. Kammen. 2007. "U.S. Energy Research and Development: Declining Investment, Increasing Need, and the Feasibility of Expansion." *Energy Policy* 35 (1): 746–55.

Natural Resources Defense Council (NRDC). 2013. "California's Energy Efficiency Success Story: Saving Billions of Dollars and Curbing Tons of Pollution." Natural Resources Defense Council, Washington, DC.

Organisation for Economic Co-operation and Development (OECD). 2014. "OECD StatExtracts Database." Organisation for Economic Co-operation and Development, Paris. http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC.

Pernick, Ron, Clint Wilder, and Trevor Winnie. 2013. "Clean Energy Trends." Clean Edge, Portland, OR.

Pierce, David W., Tim P. Barnett, Hugo G. Hidalgo, Tapash Das, Céline Bonfils, Benjamin D. Santer, Govindasamy Bala, Michael D. Dettinger, Daniel R. Cayan, Art Mirin, Andrew W. Wood, and Toru Nozawa. 2008. "Attribution of Declining Western U.S. Snowpack to Human Effects." *Journal of Climate* 21 (23): 6425–44.

Popp, David. 2001. "Induced Innovation and Energy Prices." Working Paper 8284, National Bureau of Economic Research, Cambridge, MA.

Robertson, Clint. 2013, August 16. "Study Finds Utility Decoupling Is Gaining Traction." DeSmogBlog.com.

Roy, Allison H., Seth J. Wenger, Tim D. Fletcher, Christopher J. Walsh, Anthony R. Ladson, William D. Shuster, Hale W. Thurston, and Rebekah R. Brown. 2008. "Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States." *Environmental Management* 42 (2): 344–59.

Savage, Nora, and Mamadou S. Diallo. 2005. "Nanomaterials and Water Purification: Oportunities and Challenges." *Journal of Nanoparticle Research* 7 (4–5): 331–42.

Sedlak, D. 2014. *Water 4.0: The Past, Present, and Future of The World's Most Vital Resource*. New Haven, CT: Yale University Press.

Shahan, Zachary. 2011. "Cleantech Investment Rose Considerably in 2010 and Since 2000." Earth and Industry, Hygiene, CO.

Standard & Poor's (S&P) 2012. "Water—The Most Valuable Liquid Asset?" CreditWeek. http://www.standardandpoors.com/spf/swf/water/data/document.pdf.

Taylor, Margaret R., Edward S. Rubin, and David A. Hounshell. 2003 "Effect of Government Actions on Technological Innovation for SO_2 Control." *Environmental Science and Technology* 37 (20): 4527–34.

Thompson, Barton H. Jr. 1993. "Institutional Perspectives on Water Policy and Markets." *California Law Review* 81 (3): 671–764.

Thompson, Barton H. Jr., John D. Leshy, and Robert H. Abrams. 2013. *Legal Control of Water Resources*. St. Paul, MN: Thomson-West Publishers.

U.S. Environmental Protection Agency (EPA). 2000. "The History of Drinking Water Treatment." U.S. Environmental Protection Agency, Washington, DC.

———. 2006. "2006 Community Water Survey: Volume 1." U.S. Environmental Protection Agency, Washington, DC.

———. 2009. "Clean Watersheds Needs Survey 2008: Report to Congress." EPA-832-R-10-002. U.S. Environmental Protection Agency Office of Wastewater Management, Washington, DC.

———. 2013. "Water Audits and Water Loss Control For Public Water Systems." EPA 816-F-13-002. U.S. Environmental Protection Agency Office of Water, Washington, DC.

———. 2014. "Promoting Technology Innovation for Clean and Safe Water." U.S. Environmental Protection Agency Office of Water, Washington, DC.

Victor, David. 2011. *Global Warming Gridlock*. Cambridge, UK: Cambridge University Press.

Victor, David, Zhou, Dadi et al. 2014. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change, Geneva. http://www.ipcc.ch/report/ar5/wg3/.

Webb, Claire. 2011. "Rate Changes Prompt Outrage From Water District Customers." *Orange County Register*, February 23; updated August 21, 2013.

Wharton, Joe, Bente Villadsen, and Heidi Bishop. 2013. "Alternative Regulation and Ratemaking Approaches for Water Companies: Supporting the Capital Investment Needs of the 21st Century." The Brattle Group, Washington, DC.

White, Sammis B., Jason F. Biernat, Kevin Duffy, Michael H. Kavalar, William E. Kort, Jill S. Naumes, Michael R. Slezak, and Cal R. Stoffel. 2010. "Water Markets of the United States and the World: A Strategic Analysis for the Milwaukee Water Council." U.S. Economic Development Administration. Milwaukee, WI.

Xue, Lisa. 2014. "Southern California Municipal Utilities Innovate with Decoupling." Natural Resources Defense Council Switchboard, Washington, DC.

Zekster, Igor S., Hugo A. Loáiciga, and J. T. Wolf. 2005. "Environmental Impacts of Groundwater Overdraft: Selected Case Studies in the Southwestern United States." *Environmental Geology* 47 (3): 396–404.

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Highlights

Newsha K. Ajami and Barton H. Thompson Jr. of the Stanford Woods Institute for the Environment, and David G. Victor of the University of California, San Diego, propose a set of forward-looking policies to promote innovation in the water sector. They call for fundamental reforms in utilities' pricing of water, systematic reviews of regulatory practices, and a new mechanism for utilities to raise revenue to finance new infrastructure investment.

The Proposal

Adjust the price of water charged by utilities so that it captures the full cost of delivery; implement tiered pricing so that consumers face the full marginal cost of consumption; and decouple revenue from the quantity of water sold. These changes would promote conservation measures by giving users better incentives to curtail water use, while also enhancing the financial stability of water utilities.

Conduct a systematic statewide review of regulatory practices and create water innovation offices to better coordinate the research and development of new technologies across the industry. The statewide review of regulatory practices would seek to minimize variation of rules across jurisdictions and related sectors, and provide flexibility to avoid blocking the timely adoption of new technologies. Statewide innovation offices can be shaped to drive any of the reforms and to support other endeavors such as information-sharing with water utilities and distributing funds for research and development.

Institute a surcharge on water usage, called a public benefit charge, to create a stable and sustainable source of funding for infrastructure investment. The surcharge would create a pool of monies that could be used to invest in research and development, to pay for adoption of new technologies, and to attract private capital.

Benefits

These reforms confront the most pressing challenges to innovation in the water sector. The authors emphasize that improving the financial sustainability of utilities through better pricing strategies and enhanced access to capital would help to unlock funding opportunities for innovative new technologies. In addition, the authors contend that regulatory reform would break down the legal protections for status quo technologies. Evidence from both the water sector, where these reforms have thus far been implemented only on a small scale, and the clean energy sector demonstrate the benefits of the proposal.

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