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Focus Article

Innovation in the water industry: barriers and opportunities for US and UK utilities

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Water utilities face a variety of challenges in meeting future demands under climate uncertainty, addressing aging infrastructure, ensuring water quality, and reducing energy use. The agility of the utility to implement innovative solutions to these challenges depends upon a variety of factors including utility governance and culture, regulatory environment, condition and performance of water infrastructure, and funding mechanisms for system improvements. The consequences of failing to meet these challenges could include environmental degradation, public health risks, and reductions in the level of service customers have come to expect, all at a highly elevated price. Two different types of water utilities are compared in this context: privately owned companies (using UK water companies as examples) and publicly owned utilities (using US municipal utilities as examples). Examples of innovation in the water industry, in the US and UK as well as globally, provide insight into the key barriers and opportunities for change. The successful drivers of innovation in the water industry are shown to include: a supportive culture at the water utility; a regulatory regime that allows or even promotes innovation; the financial ability to undertake research and implement improvements; and crucially, the backing of the public. Ultimately, neither the municipal nor the private model is perfect but the best elements of these could be combined as the basis for an innovative water utility of the future.

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INTRODUCTION

Global challenges related to water availability, aging infrastructure, ensuring water quality, and energy use reduction will require innovative solutions. Yet, the water sector is considered conservative and risk averse. This paper examines innovation in the water industry from the perspective of a water systems engineer with more than 20 years of experience in developing strategic plans for water utilities, working both in the US and the UK. Two different types of water utilities are compared here: privately owned companies (using UK water companies as examples) and publicly owned utilities (using US municipal utilities as examples).

Both types of water utilities face similar challenges, with assets that are reaching or have already reached the end of their useful service life and now require replacement or upgrading at a significant cost. To evaluate the potential for innovation and the barriers to achieving change, it is important to consider a variety of factors including water utility governance and culture, regulatory environment, condition and performance of water infrastructure, and funding of system improvements. Examples of innovation in the water industry, in the US and the UK as well as globally, provide insight into the key motivations for change. Ultimately, neither the municipal nor the

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private model is perfect but perhaps the best elements of these could be combined for an innovative water utility of the future.

BACKGROUND

As of 2010, there are 52,873 regulated community water systems in the US, serving approximately 300 million people.[1] In addition, there are 87,672 transient non-community systems that serve an estimated 13 million people on an irregular basis, such as campgrounds or restaurants, which have an individual water supply (typically in rural areas). There are also 19,400 non-transient non-community systems that serve water to the same people on a regular basis, such as schools or factories that have an individual water supply (again, typically in rural areas). Non-community systems are often overseen by maintenance staff or plumbers who are not formally trained in water system operation.

The situation is very different in the UK, with a total population just over 64 million and 26 private water companies providing drinking water in England.[2] A single semi-governmental water company provides services in each of Wales, Scotland, and Northern Ireland.[2–4] In England, there are nine companies that also provide wastewater services.[5] Several private supplies, similar to the non-community systems in the US and predominantly rural areas, also operate across the UK and are regulated by the local authorities. The current regime of water company regionalization and private ownership has been in place since 1989.

Innovation

The Oxford English Dictionary defines the verb 'to innovate' as 'to bring in (something new) the first time' and 'to make changes in something established'.[6] For the purposes of this paper, the focus is on transformative innovation that makes a significant change to processes or technologies rather than incremental change that makes small improvements to specific areas within a water utility. The water industry is notoriously slow to implement change, often embracing tradition and tried-and-true methods for achieving their goals. This conservatism, while partially justified by the importance of the water utility's mission, is further reinforced by the strict regulatory environment under which they operate. In the UK, the water companies are reported to invest just over one half of one percent of their capital expenditures on research and development.[7] Estimates for US research investment are difficult to make across the diversity of water utility sizes and types as many US utilities do not explicitly allocate a budget line item for research. At present, the Water Research Foundation, which is the primary industry-related research organization in the US for drinking water research, lists 817 US utility members (out of more than 50,000 public water systems).[8] The Water Environment Research Foundation, which provides industry-based research on wastewater and stormwater issues, currently has 180 US utility members.[9]

Innovation is often associated with advanced technology, such as advances in computers or mobile phones. Such a focus drives research and development within the technology fields but does not address some of the barriers to innovation in a water utility today. Water utilities generally rely on external parties, either research institutions or supply chain companies, to perform the research work and deliver pre-tested advances. The lack of direct participation in research by water utilities makes it difficult for them to fully integrate innovative practice into the company culture.

Successfully innovative companies in other industries have put research, new ideas, and a culture of change at the center of their core business. But if the focus of a water utility is the provision of water services within a heavily regulated climate, their effort is directed to ensuring public health by meeting regulatory requirements (first goal) and keeping water services running (second goal) rather than to innovation. In a municipal context, a third goal might be the support of political initiatives; while in a for-profit context, financial considerations might take precedence over research and innovation. This situation leaves innovation at best as a fourth goal.

Expecting water utilities to increase the importance of innovation within the current environment is perhaps naïve. However, much of a water utility's focus is dictated by the regulator, so this fact provides the opportunity for regulatory support of innovation. In service industries, the company focus is often driven by customer service scores and feedback, so customers can also play a role in spurring innovation for the water utilities.

FACTORS INFLUENCING INNOVATION

Governance and Culture

While similar in many aspects, the main difference between the US and the UK water systems is private ownership. England privatized water services in 1989 and now the majority of systems are run by large, regional companies as a for-profit business. Wales, Scotland, and Northern Ireland operate as non-profit, semi-governmental water authorities. In the US, the majority of water systems (approximately 80%) are publicly run by municipalities or semi-governmental water authorities. In municipalities, the director of the water utility reports to the elected council government; while in water authorities, the director reports to an elected or appointed board.

Many US municipalities view provision of water services as both a duty to residents and a vital part of their local sovereignty and as such do not want to relinquish control to neighboring cities or private companies. Water services also provide a source of revenue for the communities. While concern for the public good is admirable, this situation can result in water services being provided by many small independent utilities, even though bulk treated water is purchased from another provider and wastewater is sent to regional treatment plants. Pinellas County on the west coast of Florida is an example of this fragmentation. With a population just over 900,000 in an area of only 280 square miles, Pinellas County is divided into 24 municipalities plus unincorporated areas. Potable water service is provided by 10 individual utilities plus 3 small systems each serving a neighborhood-sized area.[10] The patchy nature of water provision in the area along with pressures on supply and battles over jurisdiction led to the creation in the 1990s of a large regional water supplier, Tampa Bay Water, to unite water services for six regional governments including Pinellas County. The regional supplier delivers bulk treated water to the member governments, who retain jurisdiction over the distribution and sale of the water to retail customers. Despite the availability of this central supply, several of the water utilities in Pinellas County remain fully independent and operate their own water treatment facilities.

While the small independent municipalities retain control over decisions about their water services, they often lack the resources to implement advanced technologies or to fund significant system improvements. Regional solutions for shortages of supply, energy reduction, and population growth are difficult to conceive in this fragmented landscape. Consolidation of smaller systems can result in significant cost savings in capital, labor, and materials.[11]

Semi-governmental water authorities offer an alternative to direct municipal control of a water utility. These authorities are non-profit with the sole focus of water service delivery, which removes them from direct political influence. Although governed by boards with elected or appointed representatives, water authorities have reasonable autonomy in making operational and financial decisions—an autonomy that is often lacking in the municipal water utility model. For this reason, water authorities can be the choice of a governance model when a municipal water utility struggles or fails.

One notable example of municipal mismanagement leading to failed water utility services and ultimately to the creation of an independent water authority is Washington, DC. During the 1970s and 1980s, Washington, DC, experienced multiple regulatory violations, diversion of funds from the water utility, suspicious contracting, and patronage appointments.[12] An estimated $96 million of water and wastewater service fees were improperly transferred to other city accounts while rates were held constant at 1987 levels.[13,14] The city was named in several lawsuits alleging numerous permit violations, lack of proper operation and maintenance, inadequate funding, a citywide boil-water alert in 1995, and 'significant risk to public health and the environment'.[13] In response to the legal pressure, Washington, DC, formed a water and sewer authority (now known as DC Water), an independent body with jurisdiction over its own budgets and operational decisions.[13] A 1996 study estimated that rate increases of 70% would be required to address chronic underfunding of repairs and improvements. The incumbent director summarized the situation as:

> We spend $7 million to $20 million more each year than we collect. The only reason we have been able to keep [the water and sewer system] operating is by living off the reserve. That can't continue.[14]

The privatized governance model so prevalent in the UK also exists in the US. Under this model, the municipality can divest itself of water assets by selling them to the private company or can retain ownership while contracting out operations and/or capital improvements, in what is termed a 'public/private partnership' (PPP). PPP companies stress that investor-owned utilities can have better and cheaper access to capital for system improvements, can generate cost savings through economies of scale and other efficiencies, and can provide greater expertise through central resources.[15] However, some cities that pursued PPP solutions in the past are now seeking to return their water systems to municipal control. For example, the City of Indianapolis, IN, recently recompeted its privatized operations contract, seeking 'partners, not vendors who use the term partnership as a euphemism for inactivity and self-interest'.[16] They awarded the contract to a non-profit utility company, similar in form to a semi-governmental water authority, citing local control, better service, depoliticizing the utility, proper investment to maintain standards, commitment to community, and tax increase avoidance as benefits for customers.[17]

With a water utility under public control, management decisions are subject to public pressure. This situation has both drawbacks and benefits: ill-advised choices based on special interests can happen but conversely the public good may be prioritized over cost when required. Political involvement in water system operation can be driven by unexpected influences, such as a recent proposal to cut off supply to a US National Security Agency data center because the state lawmakers disapprove of the collection and analysis of personal data.[18] A municipality faces a difficult juggling act to balance budgets ranging from transportation and social services to waste disposal, sewerage, and potable water, but with all of those services under the jurisdiction of a single decision-making body, the opportunity does exist to make reasonable trade-offs for holistic service management. In municipalities where there is public backing to invest in water services, customer rates are supporting innovation through initiatives such as accelerated pipe replacement, water quality sampling beyond minimum regulatory requirements, research, development of new sources in advance of climate change, and building reserve funds for future capital projects.

The UK water systems began as private systems in the 1800s but were largely municipalized in the urban areas by 1900. Smaller systems merged as the urban areas expanded such that by the mid-1970s, there were about 200 municipal water utilities in operation. In 1974, these municipal companies were further merged by river basin area into 10 Regional Water Authorities (RWAs) with jurisdiction over all aspects of water management including regulation as well as operation of water and wastewater services. Municipalities had representation on the governing boards of the RWAs and in many cases still operated the systems under contract to the RWAs. No compensation was paid to the municipalities for the loss of their assets.[19] Some private systems continued to operate separately throughout this time.

The RWA boards had potentially conflicting responsibilities for both the operation and maintenance of facilities and the regulation of facility performance, setting the stage for performance issues to be overlooked or ignored. Municipal representation on the RWA boards was gradually reduced until 1983, when it was fully removed. In 1989, the RWAs were fully privatized in response to the need for significant capital investment into water infrastructure, without increases to public debt, and to address operational inefficiencies. The regulatory structure, including the Water Services Regulation Authority (Ofwat) for economic regulation was also created at this time.[7,19] Water quality regulation is the responsibility of the UK government Department of Environment, Food and Rural Affairs, which subsequently created the Environment Agency (1996) and Drinking Water Inspectorate (1990) to focus on environmental and potable water quality, respectively.

Under municipal and regional governance prior to privatization, the UK water companies were also vulnerable to underinvestment and mismanagement as in the US. For example, the city of Leeds operated its wastewater treatment system for 24 years after the formation of the RWAs; in this case, the Yorkshire Water Authority (YWA) in 1973, as an agent of the YWA. By 1983 declining investment in the wastewater system, which now included many rural and outlying districts, resulted in a state of disrepair and poor effluent quality performance.[19,20]

The water companies currently operating in the UK, especially those that provide both water and wastewater services, are large corporate entities with complex management structures, many of which are designed to support the financing of extensive capital upgrades. Ofwat currently predicts an investment of £43 billion over the next 5-year cycle.[21] In 2013, the water companies collectively made a profit of £2.05 billion, while paying corporation taxes of only £2.3 million.[22] A shift in company culture to emphasize financial metrics seems inevitable in the face of this reality:

> The increasing use of the term ‘customers’, instead of ‘the public’, succinctly expressed the changed nature of the relationship between the water industry and those whom it served.[20]

As with any organization, the culture of a water utility is ultimately shaped by its leadership and mission. Municipal water utilities, while purportedly working for the public good and providing a necessary service, can be inefficient and distorted by politics. Procurement rules requiring full competition mean that low bid solutions are generally the norm and opportunities for innovation can be difficult to find, particularly when capital and operational expenditures are not considered holistically. Water engineering expertise, while necessary for the proper operation of a water system, is not always valued in a politically- or financially motivated environment. Outsourcing of technical expertise, which occurs in both the public and private utilities, is viewed as a low-cost solution but can leave the utility vulnerable and unable to react to changes or develop its own strategic plans. As internal teams are dissolved, the institutional knowledge that is critical for understanding complex systems and quickly responding to problems is diminished.

Regulatory Regime

The regulatory regime plays a significant role in directing the actions of water utilities, as performance is usually targeted toward measured indicators. The USEPA federal regulations set a baseline standard for water utility performance, typically as measured outcomes such as the maximum concentration of pollutants. Very few regulations describe how a water utility should meet requirements, so the choice of solution to meet the endpoint goal is within the utility's control. These federal regulations are then adopted and administered by the States, who are responsible for enforcement. States can adopt the federal requirements directly or can make changes, as long as the adjustments are demonstrated to be as strict as the original regulation. A similar situation exists in the European Union (EU), where standards are set at the EU level and administered by each member state, which in the case of England and Wales is DWI for water and the Environment Agency (EA) for wastewater and natural water sources.

A key difference between the US and the UK regulatory framework is the existence of an economic regulator in the UK, Ofwat. Ofwat must approve the business cases put forward by the water companies to set rates and regulate expenditures. Through this avenue, Ofwat can place financial penalties on companies for regulatory noncompliance (e.g. with water quality or customer service requirements) or reward them for good performance. In the US by contrast, penalties for small-scale noncompliance typically take the form of indirect costs, such as public notification by mailing pamphlets. If the problems are corrected and no further violations occur, additional fines and penalties are rare. In extreme cases involving significant and/or prolonged noncompliance, enforcement takes the form of civil and/or criminal legal proceedings against the water utility.

The most common issue in the US which leads to such legal proceedings has been combined sewer overflow (CSO) or sanitary sewer overflow (SSO) events. The USEPA enforcement website currently lists 42 settled civil cases since 2001 related to sewer overflows for water utilities; many others are still under negotiation.[23] These consent decree cases include a fine and a negotiated program of system improvements over a 20-year time horizon, amounting to billions of dollars of investment to reduce or eliminate sewer overflows.

Rule-making in the US is often a negotiated stakeholder process. Although it has the ability to propose and finalize new regulations on its own, the USEPA can also choose to consult the regulated community during the rule-making process. A federal advisory committee is formed comprising stakeholder representatives from the public, affected businesses, and the regulated entities. If this advisory committee can reach agreement-in-principle on proposed changes to regulations, the rule-making process is more likely to conclude without involving legal proceedings. Because the stakeholder negotiations can be lengthy, often on the order of several years, new regulations are slow to emerge. Furthermore, once a new regulation is promulgated, there is typically a lag time of 3–6 years before the required compliance date to allow for states to modify their regulations and put compliance monitoring programs into place. Therefore, it is not uncommon for 10 years or more to pass between initiation of the regulatory process and the date of required compliance for water utilities. In the UK, EU directives also provide several years for adoption of new regulatory requirements.

Condition and Performance of Water Infrastructure

The water infrastructure in developed countries was primarily built during periods of population growth and public social reform. In the UK, many of the water and sewer systems were built in the late 1800s, with incremental updates and expansions occurring ever since. In the US, there are regional differences resulting from patterns of growth over the last century. In the older cities of the east, initial construction began in the early 1900s and was supplemented by a boom in development following World War II in the late 1940s. In the western US, urban expansion primarily occurred after World War II. In both cases, while some pipe replacement has been undertaken since original construction, the systems have largely remained in continuous service without significant upgrades.

As a testament to the engineering work of the past century, current water systems in both the US and the UK are largely performing adequately and meeting modern regulations for potable water and wastewater effluent discharge quality. However, the numerous cases requiring litigation by the USEPA for sewer overflows and the increasing trend of pollution incidents being reported by the EA indicate that the current infrastructure may be reaching its limits of optimal performance. Replacement of deteriorating infrastructure, primarily of sewers subject to infiltration of rainwater due to poor structural condition, is a key focus for improvement under the US consent decrees.[5,23]

For potable water systems, leakage has been used as an indicator of network performance and has been a significant area of focus for the UK regulators in the past decade.[5] Although leakage has been reduced during this time, further efforts to go beyond the economic level of leakage are not currently proposed. The economic level of leakage is determined using calculations to balance the financial benefit of water savings against the cost of repairs or pipe replacement. Under this strategy, 11 water companies have no further leakage reduction targets through 2015, despite estimates that across the UK, approximately 25% of treated water is lost due to leaks.[24] In the US, the American Society for Civil Engineers develops an annual report card for America's infrastructure, with scoring at the state and national level for 16 different infrastructure elements including water and wastewater. Overall, the 2013 rating for all infrastructure is a D+, with drinking water and wastewater performing slightly poorer than other areas by scoring a D. This report estimates that 240,000 water main breaks occur each year in the US.[25] While leakage statistics are more difficult to determine because of a lack of required reporting, estimates put the US average leakage rate at approximately 16%.[26]

Affordability and Funding of Improvements

There are many arguments for and against water being a universal human right. The current debate on affordability of services, particularly utilities like water, electricity, and gas, is one example of such arguments. But the use of the term affordability misdirects attention in several ways. If citizens of a country cannot afford to pay for housing, food, and basic services such as water—all of which come at a cost—then a poverty issue exists that is not the responsibility of any individual service provider (landlords, grocery stores, water utilities). Putting aside the concept of water as a universal human right, the current systems in the developed world have linked private enterprise and payment to the delivery of clean water for more than 100 years.[19,27] So the banner of affordability places the emphasis on the water utility to deliver a continuously improving service for a continuously decreasing price, using deteriorated infrastructure in an economic climate of inflation for labor, materials, and energy. Other service providers such as landlords and grocery stores are not under such pressure to reduce prices and increase affordability.

The governmental and media discourse about affordability has singled out water and, to some extent, energy bills as looming threats to the poor. In certain jurisdictions, water service can be canceled if the customer does not pay, such as the recent American case in Detroit where a judge ruled there is 'no right to free water'.[28] In other jurisdictions as is the case for the UK, water services cannot be canceled and the water provider must continue to maintain service without payment, possibly for years and years. In Ireland, as plans to charge for water for the first time have been implemented, residents have protested in the streets, despite the clear need for infrastructure upgrades to ensure continued service.[29]

The public does not always desire centralized water services. A small privately owned rural water utility in Kentucky has been recently forced to shut down operations, leaving its 55 customers to arrange their own water services by drilling individual wells or purchasing water. The case cited a dwindling customer base, with more than half of accounts in arrears, and an inability to finance the required infrastructure improvements to keep the system operational. The regional government has not expressed an interest in providing water service to its residents.[30]

In the privatized model, the government economic regulator, Ofwat, has the final say on setting rates that customers will pay. This rate-setting operates on a 5-year cycle and covers investment for system upgrades, operational costs, and allowable profits. The latest round of rate setting promises a decrease in average water and sewer bills of about 5% between 2015 and 2020 when adjusted for inflation.[21]

The US has no federal or state control over rates charged for water services, although most states have a public utility regulation board to oversee the formation and operation of utilities including water. For publicly owned water systems, the authority board or municipal elected council typically makes decisions about rates on an annual basis with a 5- or 10-year planning horizon used to inform choices about investment. Profit is not a part of the rate-setting consideration but municipalities can choose to set aside a portion of annual revenue to fund future investment in infrastructure.

Despite the difficult economic conditions, many municipal water systems in the US have pushed ahead with plans to rehabilitate and replace their water infrastructure. Some of these plans have been driven by the regulatory consent decrees but many utilities have voluntarily taken the difficult position of justifying the need for improvement to their customers. With federal governmental focus on infrastructure as a driver for economic recovery, these programs of stakeholder education about rate increases have largely been successful. Figure 1 illustrates rate increases since 2002 for select utilities across the US including large metropolitan areas and smaller cities, ranging from 85% to 230%.[31]

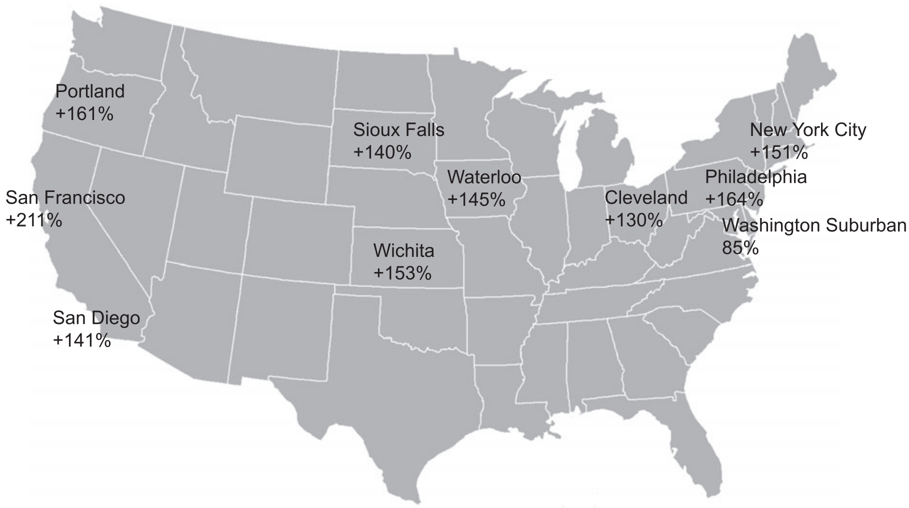

FIGURE 1 | Selected rate increases for water and wastewater services over the past decade.[31]

EXAMPLES OF INNOVATION IN THE WATER INDUSTRY

Singapore is often held up as an example of water innovation, having transformed its water situation over the last 50 years from that of a country with little centralized sanitation and reliance on imported water to a world-leading research and development 'hydrohub'.[32] Singapore is a densely populated island with nearly 5 million residents and, despite enjoying significant rainfall, lacks the land area to develop significant natural water sources. Singapore's long-term strategy for water self-reliance includes four 'taps': local catchments, imported water, highly purified reclaimed water known as NEWater, and desalinated water. Local catchments for rainwater collection now account for two-thirds of the land area on the island.[33] Imported water from neighboring Malaysia currently provides 40% of the required supply and NEWater provides 30%, although plans are underway to expand the NEWater capacity to 60% by the year 2060. Desalination makes up 25% of the current supply with expansion plans aiming to double that amount by 2060 to facilitate independence from imported water sources.[32,34] Corresponding upgrades to sewage collection and treatment facilities were made to ensure that the catchment resources are not polluted. Water demand management is also a vital part of the plan, with a current per capita use of 151 L per day,[32] which is similar to the current UK water consumption levels.[35]

Studying how Singapore achieved such a turnaround in a relatively short time period provides some insights into innovation in the water industry on a large scale. The key factors in this story are a clear vision, the political will and power to carry out the vision, and an investment on a massive level. The scale of changes that happened in Singapore reflects the severity of the problem of rapid urbanization and the lack of infrastructure in that particular location. Tensions are likely to continue over land use management as different agencies compete for dwindling available space, so a continued political will to prioritize water is essential.[33] An outreach program has been developed in recent years to more fully engage residents and businesses in valuing and managing water resources. The investment in cutting-edge water infrastructure ranges into the billions but has put Singapore on the map as a center for water and environmental technologies, now boasting 130 water companies and 26 research centers backed by governmental support of $470 million to promote a 'thriving and vibrant research community'.[32] The political power required to allocate valuable land to water collection and storage, including transplantation of entire neighborhoods, is not likely to be available in other parts of the world under non-crisis conditions.

Singapore is an extreme case of water sector innovation but there are smaller examples that can be instructional from the US and the UK. Since the privatization of the UK water industry in 1989, leakage has been a key area of focus for regulators. Through leakage reduction targets and associated financial penalties for missing those targets, Ofwat was able to draw attention of the industry (and perhaps more importantly, investment) to the issue. While the value of achievements in leakage reduction, which Ofwat reports as 35% since the 1994–1995 peak,[36] can be debated,[24] an equally important outcome has been rapid innovation in leak detection and repair technologies that now places the UK as the world leaders in leakage mitigation.[37] The International Water Association (IWA) water audit procedures, developed through extensively drawing on experience from the UK water industry leakage work, have now been adopted as a standard in many countries around the world including the US.[38] The global leakage minimization and pipeline rehabilitation market is estimated at $3 to $5 billion, leaving the UK in an enviable position to further expand its water innovation industry.[37]

The example of leakage mitigation illustrates the potential for innovation spurred by regulatory requirements and funding availability. The growing environmental awareness and negative attitudes toward wasting water among the public was also a supportive factor, although indirect. The water companies had access to the necessary capital to finance research and development into leakage detection technologies and had a clearly defined reward for making such a research investment. Today, the UK water companies have an internal team specializing in leakage within their organizational structure, which is not the case in US utilities. University and private sector researchers in the leakage field also benefitted from the support of research and investment in laboratory facilities.

In the mid-1990s, the City of Philadelphia began evaluating ways to reduce or eliminate its estimated 16 billion gallons of combined sewer overflows per year. Engineered solutions such as overflow storage tunnels and wastewater treatment plant capacity upgrades were considered but the costs were thought to be prohibitive and the proposed solutions did not address related environmental enhancements such as stream restoration or municipal challenges such as neighborhood deterioration. Like many other US utilities, Philadelphia was facing a consent decree settlement with regulators, which would likely require billions of dollars to be invested in infrastructure.[39] Through an innovative program of research and outreach, against a background of heightened public awareness, thanks to several large flooding events, Philadelphia was able to successfully negotiate a CSO management plan entitled 'Green City, Clean Waters', which included extensive investment in green infrastructure instead of traditional gray infrastructure like sewers and tunnels. This plan maps out a $2.4 billion capital expenditure over a 25-year period, including $260 million for stream restoration, to eliminate a pollutant load equivalent to capture of 85% of the volume in the combined sewer system on an annual basis.[40]

Key factors in the success of Philadelphia's plan were the regulatory drivers to secure funding, political backing, and popular support; it is unlikely that a city in poor financial condition like Philadelphia would have invested billions of dollars in stormwater infrastructure on a voluntary basis. Urban renewal is a key issue for Philadelphia, so by using the opportunity provided by the CSO regulatory requirements, the city was able to couple neighborhood and environmental improvements in an innovative way. Political support was required to pass strict development and redevelopment ordinances and to transform the generally invisible water department into a highly visible part of local government that reviews development plans, improves parks, and provides recreational water resources for residents. The city has recruited many stakeholder partners to help install and maintain green areas in accordance with the plans. However, the ability of this ambitious plan to deliver tangible results in terms of pollution reduction remains to be proven—so this case also demonstrates the ability of the regulators to accept a degree of risk, which is necessary but by no means sufficient for innovation.

Potential Impacts of Lack of Innovation

Water utilities are being asked to perform an impossible feat of providing water of higher and higher quality while using less energy, fewer chemicals, having fewer outages, and drawing against a potentially insufficient supply. Many of the dynamics of system operation are dictated by customers who make water use choices beyond the control of the utility. To date, water utilities have not met this challenging brief: for instance, the energy use by UK water companies has doubled since 1990, largely in response to tightening water quality regulations and increases in demand, and energy consumption is on track to double again by 2030 without intervention.[7]

A nuanced complexity within the water industry is the dilemma of water conservation. Water conservation is a cornerstone of supply management, particularly under drought conditions. Based on climate projections for the UK, southern areas could face rainfall shortages of 40% during summer months, so conservation measures are likely to be an increasingly important supply management tool.[41] Yet conservation relies on customer participation and, under current volume-based rate structures, forces water utilities to campaign for a loss in their own revenue. The UK is particularly hampered in water conservation innovation because of a lack of consumer information and national standards on water use for plumbing fixtures. For example, a search for a home improvement store website reveals no information on flow rates for shower heads, except for a general statement that aerating shower heads could save up to 75% of water. Links to such products were not provided.[42]

One solution to this lack of demand management innovation in the UK can be found in the US, which has had low-flow plumbing fixture standards since the mid-1990s. Since 2006, the USEPA WaterSense program has been developing standard specifications, enrolling partners, and labeling conforming products in collaboration with a wide variety of stakeholders including builders, plumbers, manufacturers, certifying organizations, trade associations, water utilities, regulators, and non-profit organizations.[43] While the program operates on a voluntary basis, it has raised public awareness about water saving fixtures and the labeling of products makes it simple for consumers to compare and select products. Many US water utilities are experiencing a slight decrease in customer consumption and the gradual retrofitting of household plumbing fixtures is thought to be one factor. For example, Washington Suburban Sanitation Commission, which serves the Maryland suburbs adjacent to Washington, DC, has seen its total water production remain relatively constant since 2009 despite adding over 14,000 new customer accounts.[44]

A larger problem is that water infrastructure is aging and replacement rates are not keeping up; for example, a replacement rate of 1% per year equates to each pipe only being replaced every 100 years. While age alone is not a complete indicator of pipe performance, current construction materials and techniques are not producing pipes that can last much longer than 100 years. As such, implementing a replacement rate of 1% on a new system might possibly be adequate. It is difficult to obtain precise data on the age distribution of pipe in the UK because as much as 60% of pipe age is not currently known[45] and water companies do not publish such data. But assuming that the average pipe age in the UK is currently on the order of 75 to 80 years, a 1% rate will not be sufficient to revitalize the systems. Figure 2 summarizes pipe failure data for the UK by pipe age category and shows that a significant number of breaks occur even in relatively new pipes.[45] While repairs are possible to extend the life of a pipe beyond a single break, the probability of future breaks is increased after the occurrence of the first one. What is required is a technological advancement to significantly extend the usable service life of pipes or a change in the expected levels of service related to outages and water quality.

In the US, many systems are newer than the UK pipe networks but nonetheless face a daunting replacement scenario. Figure 3 illustrates the age of water mains in a Midwestern US city that serves a population of about 1 million people. The system has approximately 3,500 miles of water mains ranging in age from new to more than 100 years old, with a weighted-average pipe age by a length of 46 years. This range of ages and configuration is fairly typical of older, eastern US cities, while western cities tend to be newer. More than 90% of the pipe is cast iron or ductile iron, with a small amount of plastic pipe.

The case study system of Figure 3 currently experiences a leakage rate of about 65 million liters per day (MLD), or 13% of a total system supply of about 500 MLD. With no pipe replacement, this system is projected to reach a leakage rate of 22.5% (112.5 MLD) by the year 2070 and this increase in leakage equates to an additional 2.5 million kWh per year in pumping energy.[46] In 2010, the utility recorded 531 bursts that required intervention. However, the number of recorded bursts accounts for a small portion of the estimated leakage volume meaning that the number of low-level unreported leaks is perhaps on the order of tens or hundreds of thousands. Based on historical trends with linear increases in break rate, the number of bursts is projected to increase by 32% by 2070, therefore requiring one third more investment in terms of labor and material to perform repairs. If pipe break rates increase exponentially, the situation will become much worse. The consequences of a pipe break can be relatively minor, with repairs completed in a few hours and only a few residents affected. However, pipe breaks on large diameter mains under high pressure can cause major disruption to traffic and roads, damage to buildings, flooding, and loss of service to large areas for days.

No pipe can be expected to perform at a high level of service indefinitely. So the lack of replacement currently being performed will translate into a massive investment at some time in the future. Under the current regulatory program in the UK, water companies are not setting aside reserves to fund this replacement. One potential outcome could be that the central government be required to step in and fund infrastructure renewal at the cost of the taxpayer to avoid environmental degradation and service outages. In the US, one possible outcome could be that local governments will face bankruptcy and cuts to social services to fund water system infrastructure upgrades. Perhaps if the public was more aware of the current situation, such future consequences could be mitigated.

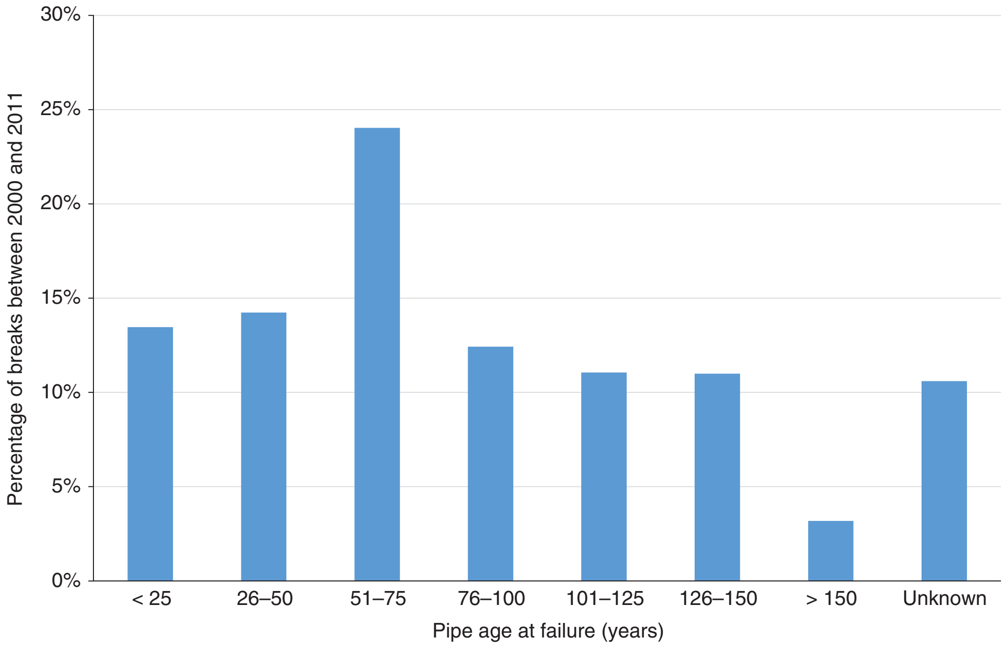

FIGURE 2 | Summary of UK pipe break data (2000–2011) by pipe age at failure.

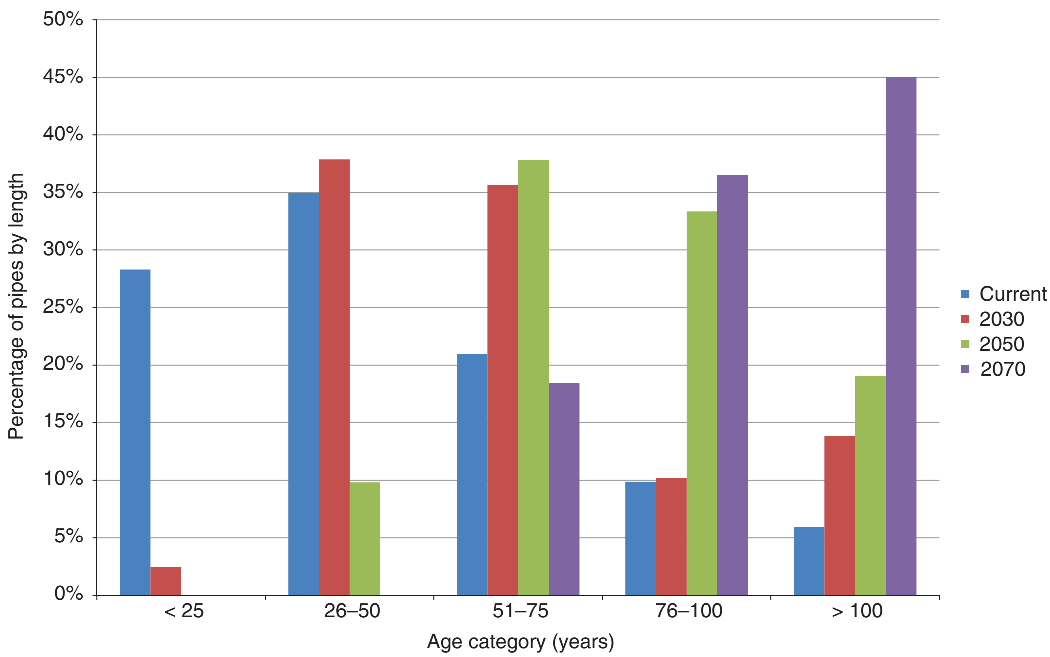

FIGURE 3 | Summary of current pipe age distribution for one Midwestern US city, with projections for pipe age if no replacement is performed.

CONCLUSION

The successful drivers of innovation in the water industry are shown to include: a supportive culture at the water utility; a regulatory regime that allows or even promotes innovation; the financial ability to undertake research and implement improvements; and crucially, the backing of the public. At present time, the water industry, under either the publicly managed or the privately owned water utility models, lacks these drivers and is not yet aligned for transformative innovation.

An examination of a variety of water utility configurations and situations can provide some insight into the attributes, which might be associated with the innovative water company of the future. The concept of regionalization is appealing, thanks to the economies of scale and the provision of resources and expertise. A regional and cross-infrastructure perspective is also necessary for capturing large-scale opportunities for supply and energy optimization across all utility services provided to residents, not just water.

The innovative water organization is one that prioritizes the delivery of water services as its primary mission; this necessitates retaining the technical expertise that is required to perform that mission. Leaning too far toward a business model (UK case) promotes financial considerations over all others; leaning too far toward a municipal model (US case) promotes political considerations over all others. Short-term thinking can be problematic in both the business and political models, which have drivers related to profit and election cycles, respectively. Perhaps the best model available today is the regional, semi-governmental water authority where profit considerations are eliminated and political aspirations are, at the least, one degree removed from daily operation. This environment also allows for long-term thinking to influence the selection of solutions and decisions about investment. Items that may seem like niceties in the current short-term financial scheme, such as setting aside capital reserves or tackling leakage aggressively, can become more favorable when a longer time horizon is considered. The size of the water utility must also be considered. Ideally, a utility should be small enough to permit agility but large enough to have a critical mass of expertise and financial capability.

But the ideal organization must also have solid public support. As such, water utilities should look to develop a relationship with the public that includes collaboration around a shared vision, mutual trust, and a willingness to partner in the responsibility for delivery of water services. In cases where this relationship has been successfully fostered, public support has been the key to increasing investment, decreasing water use, and the uptake of innovation. Public support can also put pressure on regulators, which do respond to political pressure, to adjust their programs.

Strong leadership and investment from regulators have been shown to be a very large driver of innovation. In the US, direct and indirect investment in research by the USEPA has made significant advances in understanding water quality, treatment, and environmental impacts. The public dialog related to infrastructure improvements in the US has created an environment in which utilities can successfully seek rate increases from their customers. However, regulatory changes move slowly in the US because of the negotiated rule-making and multi-level institutional support that is required, which could hinder quick wins in innovation.

Based on the availability of capital, the UK water companies should be better positioned to implement innovation than publicly funded US utilities. Yet the UK companies need a regulatory driver to justify innovation expenditures within their short payback periods. Ofwat is uniquely positioned to increase spending on innovation and infrastructure replacement, both of which will soon be needed to meet the challenges of increased water demand, high public expectations about service and water quality, and energy efficiency.

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