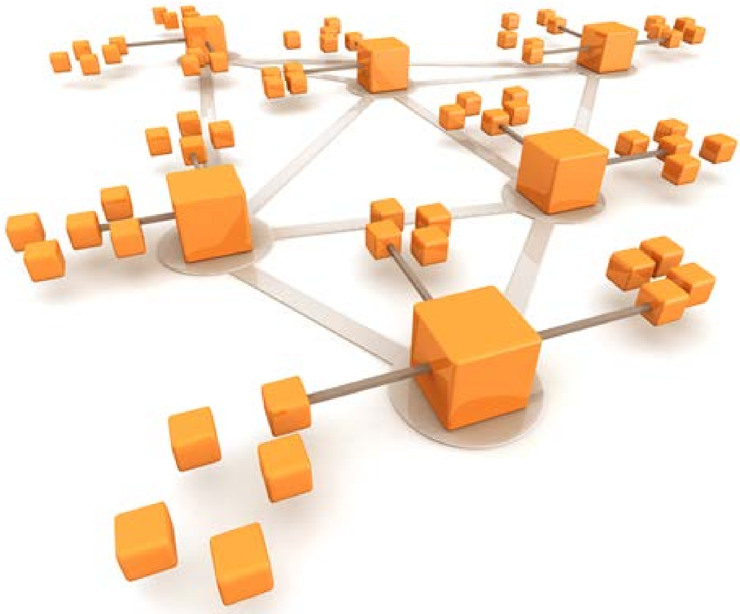

Trends in the U.S. Water Market Shaping Technology Innovation

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1 Executive Summary

The US water market—and the new technologies that will increasingly define its growth—are entering a new era. Increased scarcity, new regulatory imperatives, public discontent over caustic treatments and practices, and the decline of the design-bid-build model (through which major infrastructure firms control supply chain) are all serving to accelerate innovation in water technologies. And investors are beginning to notice. While venture capital has historically been slow to flow to water ventures (representing only 2-3% of total venture dollars invested in clean technologies), this is beginning to change. Global venture capital within the water sector rose to $258 million in 2011, and accounts for nearly 5% of total investment thus far in 2012, and mergers and acquisition (M&A) activity reached a historic high of $16.2 billion in 2011—a trend that is continuing through the first quarter of 2012. Such numbers reflect the rising interest in water and wastewater solutions from investors and major corporates that we at Cleantech Group have encountered for several years now.

In this report, we detail ten technology and market segments (with current market sizes across both equipment and services) where we are seeing high concentration of innovation and deployment:

1. **Filtration** ($2.2B in 2011): We observed improvements in sand filtration, ion exchange, and granular activated carbon, though the highest levels of innovation concern membranes, which continue to dominate the filtration market with significant efficiency gains and cost reductions. New technologies such as nanofiltration membranes are increasingly showing promise for not only controlling pathogens and filtering a diversity of contaminants, but doing so utilizing less energy and creating less waste.

2. **Disinfection**: ($2.25B in 2011, excluding chemicals) Ultraviolet (UV) disinfection technologies are growing rapidly as regulations and the general public call for higher quality water, fewer chemicals, and increased efficiencies; but the most promising approaches are now combination techniques (e.g., UV + ozonation).

3. **Water Quality Monitoring**: ($900M in 2011). In addition to multi-parameter sensors, much innovation has centered on optical sensors, which provide indirect measurements of water quality changes by monitoring variance in light through the sample water volume. These optical sensors are gaining some deployment momentum as they require minimal operational maintenance and are comparable in price to the more traditional sensors.

4. **Smart Water Metering**: ($640M in 2011). Though a few years behind electric meter deployments, smart water metering—and the analytics and applications they enable—is being deployed at an accelerated rate, with the US dominating the market (65% of all global shipments in 2010[1]). In total, the smart water metering market is estimated to be $640 million in 2011.

5. **Infrastructure Assessment**: ($260M in 2011). Though a nascent market, there is an increasing demand for non-destructive detection techniques (for pipe failures, leaks, etc), such as cameras, closed circuit television (CCTV) and acoustic leak detection technologies.

6. **Water Reuse:** ($1.0B in 2011). As water scarcity remains an imminent concern and desalination still proves to be a costly option, water reuse remains one of the hottest topics in water. Membrane bioreactor approaches are increasingly favored as they produce high quality effluent suitable for discharge to coastal waterways or use for urban irrigation.

7. **Nutrient Recovery:** ($10M in 2011) Nutrient recovery is a nascent market. However, there is renewed focus on nutrient recovery given the increasing value of resources such as phosphorous and nitrogen. Innovative solutions are reducing energy requirements and extracting nutrients without chemicals, while offering utilities a new revenue stream.

8. **Distributed Small Water Facilities:** While small water facilities face the same treatment regulations as large water facilities, they are exploring alternative packaging and delivery

[1] *The World Market for Water Meters – 2011 (IMS Research)*

of treatment solutions. For example, smaller facilities that do not operate full-time are increasingly opting for preassembled units that are available at a lower cost.

9. **Green Infrastructure / Wet-Weather Flow:** ($680M in 2011). Cities are increasingly investing millions in green infrastructure to manage stormwater, with common solutions including green roofs, permeable pavements, gravel ditches, and retention basins. New technologies that are increasingly utilized include moisture sensors and soil probes (to measure infiltration), roof flow measurements, and flow meters.
10. **Ballast Water:** ($2.9B in 2011) Poised for growth upon the impending adoption of International Maritime Organization (IMO) regulation, a host of new ballast water treatment technologies are being adapted from trusted land-based techniques, with the most prevalent systems being those that combine mechanical separation/filtration with UV radiation or chemical disinfection.

2 Market Overview

2.1 The US Water Market

The US water market has been hard hit over the past few years. The global financial crisis caused many large industrial companies to postpone or cancel major water investments. It also affected public budgets and the ability of municipalities to secure low-cost financing. While federal stimulus funding propped up the market in 2010 and 2011—the American Recovery and Reinvestment Act (ARRA) contained nearly $14 billion for projects in water infrastructure—municipal capital investments will likely dip in 2012 with the withdrawal of stimulus funding.

Despite the recent turmoil, the market is recovering. The overall US water market for equipment and related services reached $82 billion in 2011 (returning to 2008 levels), and is projected to grow at a mild-but-steady 4% compound annual growth rate (CAGR) to reach $100 billion by 2016.[2] Starting in 2013, the increasing demand generated by regulatory necessity (e.g., consent

[2] *Water Market USA 2011 (GWI 2010)*. Notably, this estimate excludes water utility revenues charged to end users—namely water bills charged to the public and industrial clients for their water usage—which have been included in some larger market estimates (for example, EBI's 2006 market estimates).

decrees), water scarcity, and failing infrastructure will supplant the expired stimulus and lead to 5-6% growth through 2016.

The present day $82 billion estimate comprises both the (i) utility segment—including capital expenditures ($34 billion) and operating costs ($46 billion)—as well as (ii) the industrial segment ($3 billion). Total services in 2011 (including both capitalized professional and contracted services) amount to nearly $24 billion (or approximately 30% of the total market).[3]

Roughly 45% of the utility market concerns drinking water, with the remainder related to wastewater. Specifically, drinking water accounts for $36 billion in 2011 (growing at 4.7% annually) and wastewater accounts for $44 billion (growing at 3.0% annually). This higher growth in drinking water is primarily driven by water scarcity and the growing need to render potable wastewater and other low quality water sources.

Breaking down by general application type, we see the equipment market is unsurprisingly dominated by infrastructure, services, and other utility operating expenses (which largely comprises utility spend on labor, energy, and chemicals).

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[3] *Water Market USA 2011 (GWI 2010).* Utility labor costs, estimated at $13 billion in 2011, are excluded from the services estimate. If included, services would total ~50% of all water and wastewater market expenditures.

Sector[4]	Total (2011)	Share
	$billions	*%*
Filtration	1.1	1.4%
Disinfection	3.7	4.5%
Smart Water	0.3	0.4%
Infrastructure	12.4	15.1%
WW Mgmt.	1.2	1.5%
Other	5.4	6.6%
Services	24.2	29.4%
Op. Ex.	33.9	41.1%
Total	**82.3**	**100%**

2.2 Sizing Select Innovation Segments

In addition to presenting a general market overview, we have sought to assess the current market size and growth potential of the specific emerging technologies detailed in this report (which are areas where we see the most innovation and growth). These segments were chosen given the level of (1) venture capital funding, (2) research & development (R&D) funding, and (3) general industry interest that we have seen in recent years. We have crafted niche market estimates—broken down by equipment and services, where possible—that measure the current revenues for companies engaged in commercializing a specific application or technology, and provided this information in the context of broader water market segments (as shown in Section 2.1). As an example, while the overall market estimate for infrastructure is $12.4 billion, (of which $4.7 billion is the rehabilitation market), the present market opportunity for companies developing innovative infrastructure assessment technologies (e.g., leak detection) is significantly smaller at an estimated $260 million (see table below).

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[4] Sector definitions:
Infrastructure: Includes pipes pumps and valves
Filtration: MF/UF, RO/NF, Media Filtration, ion exchange, membrane bio-reactors
Disinfection: Disinfection systems and chemicals (opex)
Wastewater Management: Sludge management and zero liquid discharge systems
Smart Water: Meters, networking technologies, and software
Other: Control systems, aeration, primary intakes, chemical feed systems
Services: Site work, pipe rehab, professional services (capex), and contracted services (opex)
Operating Expenditures: Utility labor, energy, and other costs

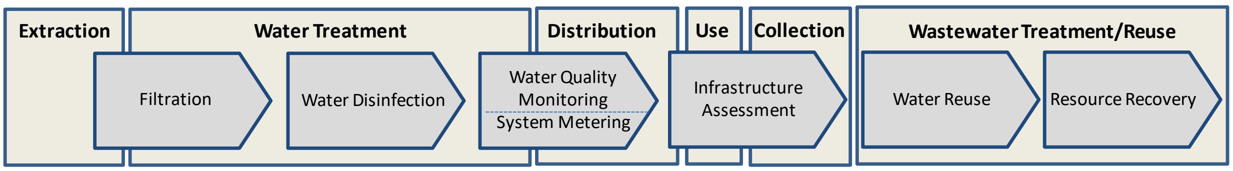
Subject to the definitions provided in Section 2.3, the following chart summarizes current market estimates (split between equipment and services based on research and primary interviews) for the innovation sectors detailed in this report. Please note that the Green Infrastructure and Ballast Water are not included in the overall water market size estimate of $82.3 billion.

Innovation Sector (2011)	Total	Equipment	Services
	$millions	*$millions*	*$millions*
Filtration	**2,200**	1,100	840-1,400
Disinfection	**2,250**	640	1,280 -1,920
Water Quality Monitoring	**900**	210	690
Smart Water Metering	**540**	310	150-310
Infrastructure Assessment	**260**	50	210
Water Reuse	**1,000**	450	550
Nutrient Recovery	**10**	3	7
Green Infrastructure	**680**	300-375	300-375
Ballast Water	**2,850**	950	1,900

In summary, the water innovation sectors that we analyzed totaled approximately $10.7 billion in the year 2011. Equipment accounts for nearly $4.1 billion of this amount (or 40%), with the remaining $6.6 billion spent on related services (we take the average of the service range for this number).

2.3 Market Definitions

Few fully contemplate the long journey water takes to reach our homes and businesses. The water cycle is quite complex; beginning with extraction (from numerous surface water or groundwater sources), transport to a water treatment plant for processing via multiple phases of treatment, then distribution across an expansive grid of pipes, customer end use, and then collection before ultimately being treated for potential reuse or returned into the environment. Technology innovation influences every step (or multiple steps simultaneously) of this water cycle. In this report, we analyze various technologies and services at different steps of this journey, as depicted in the graphic below.



The first water cycle market segment we address is water treatment. In this phase, water is treated to various levels of purity based on expected usage of the treated water. For example, water destined for irrigation to farm fields faces lesser standards, while the highest level of treatment is reserved for drinking water.

There are many treatment methods used to render water potable, including **aeration** (the process of increasing oxygen saturation of water to allow for the release of noxious gases such as carbon dioxide, methane, or hydrogen sulfide), **coagulation** (treating water with chemicals that neutralize particle charges and cause them to clump together), and **sedimentation** (allowing heavier particles to sit to the bottom of a sedimentation basin using the force of gravity). The two primary methods of treating water are **filtration** and **disinfection**, which we cover in more depth in this report:

- **Filtration** is the process of passing water through a porous device to remove impurities or other particles that could not be removed in other pre-treatment phases. While there are many filtration techniques in use today, the bulk of innovation resides with the membrane. Membrane technologies rely on thin, permeable layers of material to separate contaminants from water. They fall into two broad categories: *pressure-driven* and *concentration-driven*. As suggested by its name, pressure-driven processes use water pressure to propel particles through a membrane filter to be separated based on size. Concentration-driven processes use osmotic pressure, which relies on a highly concentrated solution (one infused with solutes that cannot pass through the membrane) to induce pure water molecules to pass through a preferentially permeable membrane. As described later, osmotic pressure is the basis for reverse osmosis filtration.

- **Disinfection** plays a key role in water treatment and is intended to remove or deactivate pathogenic microorganisms (e.g., bacteria, protozoa, viruses and parasitic worms). Disinfection agents range from *chemical* disinfectants (e.g., hypochlorite, chloramines, or ozone) to *physical* disinfectants (e.g., UV, electronic radiation, or heat). It is the physical disinfectants that comprise the large majority of disinfection equipment, and therefore innovation in the sector.

Once collected water is treated by one or more of these approaches, it is ready to be distributed to end users for consumption and use. The water travels through a network of storage tanks and pipes that connect the treatment facility to residences, commercial businesses, farms, and a host of other water consumers. Upon being released from the treatment facility, the water is monitored for turbidity and residual chlorine levels. While the water leaving a treatment plant will typically meet EPA water quality standards, the water is susceptible to changes in quality as it passes through the water distribution system. To ensure the water is safe at any given end point in the water network, treatment facilities rely on various water quality monitoring technologies (or grab sampling methodologies) to periodically assess water purity at numerous points along its journey. Further, by identifying points of potential contamination, these monitoring solutions also help to assess the physical condition of the distribution network. This report details three technology segments related to the monitoring of water quality and use:

- **Water Quality Monitoring** technologies enable utilities to detect the presence of specific contaminants that are either regulated by EPA or indicative of potential network weaknesses (e.g., pipe breaks, bio-fouling, or corrosion). Water utility operators rely on these sensors to alert them of any water quality anomalies and take further actions to identify and quantify the contaminant, if necessary. Traditional water testing technologies include sensors that test for one contaminant at a time. Other sensors capable of testing for multiple contaminants exist, but are typically more expensive.

- **Water Metering** allows utilities to monitor how much water is being distributed and used by its various customers. While metering itself is not a new concept, new deployments often focus on "smart" metering systems that overlay digital sensing, communication networks to transmit collected data, and analytics to drive new applications. Such systems obviate the need for manual data collection (e.g., meter readers), but the data itself is increasingly valuable. Rather than monthly reads, smart water metering systems now enable readings at hourly intervals (or less), which offer utilities a detailed understanding of water usage across their distribution system, and end users insight into how they are consuming water (and thus how they can reduce inefficiencies). As such, the bulk of the market in terms of dollars is allocated to services that facilitate a utility's ability to use and act upon the collected data, rather than to equipment. Smart water meters consist of first generation automatic meter reading (AMR), which merely transmit usage data to the utility, and newer advanced metering infrastructure (AMI), which offer two-way data communication that can enabling numerous services through the meter (e.g., demand response, variable pricing, etc.).

- **Infrastructure Assessment** refers to the evaluation of the integrity of pipes, pumps, and valves within water and wastewater distribution networks. While within the broader context of water infrastructure, this sub-sector is related specifically to allowing utilities to quickly pinpoint problems caused by aging or damaged infrastructure. The infrastructure assessment market is closely related to water metering, as water meters allow utilities to identify potential leaks, yet the solutions go beyond metering insofar as they detect various factors that impact a pipe's ability to transport water at a required quality, flow rate, and pressure. High pressure is often cited as a main concern for utility operators, as this is what causes bursts and leaks. Some basic solutions measure these various parameters (water quality, flow rate, pressure) at the beginning and end of a section of the water distribution network, although these solutions do not offer insight into origin of the problem or continued pipe performance. Increasingly popular are solutions such as visual inspection, electromagnetic inspection, and acoustic monitoring technologies, which can enable deeper diagnoses of water infrastructure problems.

After the treated water is distributed and consumed, it is collected and transported back to a wastewater treatment facility. Wastewater is typically treated by some combination of physical, chemical, and biological methods, and then typically discharged into surface waters. The wastewater treatment process can be split into three separate steps: primary, secondary, and tertiary.

1. *Primary treatment* is meant to produce an effluent (i.e., liquid waste) suitable for biological treatment. This step often consists of temporarily holding of collected sewage in a dormant basin to allow heavy solids to settle to the bottom while oil, grease, and lighter solids float to the surface. The settled and floating materials are removed, and the remaining liquid is discharged and subjected to secondary treatment.

2. During the *secondary treatment* phase, the wastewater discharged from the primary treatment is treated through biological oxidation to remove dissolved and suspended biological matters. This step may require a separation process to remove microorganisms from the treated water prior to discharge or tertiary treatment.

3. *Tertiary treatment* uses additional physical, chemical, or biological means to further improve the effluent quality. This step typically uses some form of filtration.

These three treatment phases are the hallmark of approaches used to ensure safe discharge of wastewater into surface water. But increasingly wastewater is being viewed as a resource in its own right—as a source for water, energy, or other nutrients. Thus, new technologies are emerging that not only seek to permit safe discharge, but also to remove and collect valuable content from the effluent stream that can be stored, packaged, and sold as a commodity (e.g., fertilizer). Our report covers two areas with notable innovation—water reuse and nutrient recovery:

- **Water Reuse**[5] refers to reclaimed water that is collected, treated, and used all in the same cycle (without releasing the treated water back into the natural water cycle). It also refers

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[5] Desalination, the process of removing salt and other minerals from saline water, is another popular alternative to increasing the global supply of potable water. While desalination is important to note, it is not covered in detail in this report as adoption has been slow due to the high costs associated with traditional thermal desalination methods, such as multi-stage flash distillation. Less costly membrane technologies such as reverse osmosis (which we do cover) have overtaken thermal technologies and led the market for the last 30-40 years.

to reclaimed water that is being priced and sold by a water supplier.[6] Technologies used in the reuse market do not differ from those already used in the drinking water and traditional wastewater treatment markets. Rather, to meet different reuse requirements, customized treatment solutions are developed through unique technology combinations. These combinations may vary based on several metrics, including characteristics (contaminants) of inflow, final water quality requirements, end use of effluent, peak flow requirements, regulatory requirements, and cost constraints. The most popular combination includes *microfiltration, reverse osmosis,* and *membrane bioreactors/advanced oxidation*, which we assess in detail in this report.

- **Nutrient Recovery** refers to new applications for capturing biosolids, the nutrient-rich organic materials that can be removed from wastewater during the treatment process for eventual reuse as a fertilizer or soil conditioner. Nutrient recovery is drawing considerable attention both because some nutrients are increasingly scarce (and valuable) and because the EPA is now regulating the concentration of certain wastewater nutrients that can lead to aquatic toxicity concerns.

Outside of the basic water cycle described above, there are many other segments adjacent to the core water and wastewater industry. Specifically, the EPA directed its focus to three unique water markets—distributed small water facilities, green infrastructure, and ballast water—which we detail below.

Distributed Small Water Facilities refers to treatment centers with flow rates lower than 100,000 gallons per day. In many ways, these facilities do not differ from their larger counterparts—both must treat drinking water to the same EPA standards. Differences do exist, however, for wastewater treatment as larger plants have a larger impact on receiving surface water due to their larger flow, and thus are held to more stringent effluent regulations.

[6] Stormwater recapture and domestic reuse of greywater are not included in our analysis of water reuse.

Green Infrastructure (or Low Impact Development) refers to strategically planned and managed projects that naturally manage stormwater to reduce risk of combined sewer overflows. Design elements such as green roofs, permeable pavements, and retention basins can mitigate stormwater runoff from exposed surfaces by collecting and retaining precipitation, thereby reducing the volume of flow into stormwater infrastructure and urban waterways. Communities are becoming more aware of these benefits and are increasingly open to "greening" new construction projects and upgrades to existing infrastructure. Measurement tools, such as moisture sensors and soil probes, are used in conjunction with these green urban planning initiatives to monitor and analyze their effectiveness.

Ballast Water denotes water that marine vessels intake at one coastal port and discharge at another in order to maintain stability during transit. Treatment technologies have evolved in response to impending new regulation and control over ballast water, as invasive microorganisms and other contaminants can migrate from port to port through a marine vessel's discharge of dirty ballast water. A large majority of ballast water treatment technologies have been adapted from trusted land-based water treatment technologies, with the most prevalent solutions combining mechanical separation/filtration with UV radiation or chemical disinfection.

2.4 Service Providers

In the US, water and wastewater treatment facilities have traditionally been delivered via a Design-Bid-Build (DBB) method. In the DBB process, municipalities contract with firms for plant design and plant construction separately, with a bidding phase in between. In the Design phase, municipalities retain an engineering firm to design the project and draft tender documents which can then be used to bid out to a construction firm.[7] The engineering firm is responsible for obtaining all permitting documents and necessary approvals. Permitting documents may include wastewater discharge permits, NPDES (National Pollutant Discharge Elimination System) permits,

[7] Sales representatives from various distribution firms typically involve themselves in this phase to ensure engineers are designing projects in such a way that specific technologies are required to best suit their application. Water treatment technology equipment vendors that do not contract with sales representatives have the potential to be overlooked for projects, as sales representatives are typically more aggressive and have a closer relationship with engineering firms than do technology vendors.

permits necessary through the US Army Corps of Engineers, air permits, incinerator permits, and a host of other permits. Towards the end of this phase, the design engineering firm may bring in civil, electrical, and other engineers and architects to help finalize designs.

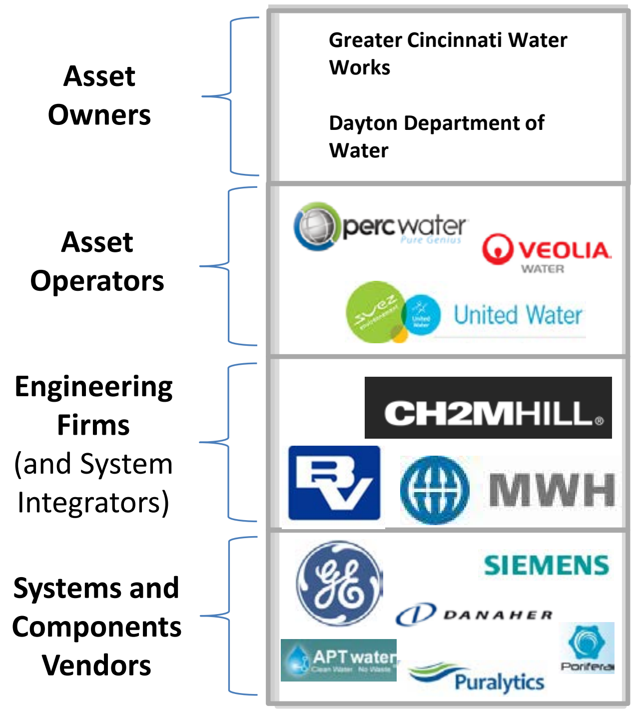
In the Bid phase, general contractors bid for the project based on the specification and their ability to build the facility according to plan. In the third and final phase, the Build phase, the selected firm will either build the facility by itself or subcontract various subcomponents of the project. The engineering firm is retained throughout the entire process for inspection (quality control) purposes.

Another model is the Design-Build (DB) approach. In this approach, there is only one point of contact throughout the entire process, as the firm designing the facility is also responsible for its commissioning. This structure allows a project to be constructed faster and cheaper, as the design phase and construction phase can overlap. However, major construction is typically postponed until all proper permits are obtained, leaving only certain activities (such as purchasing supplies and materials) that can be done simultaneously with the design phase. This model is often reserved for more technologically advanced projects within the US, but it is fairly common outside of the US.

Other project delivery methods include the Design-Build-Operate (DBO)—in which an Operations & Management firm is brought in as the final step, the Build-Operate-Transfer (BOT), the Build-Own-Operate-Transfer (BOOT), and the Build-Own-Operate (BOO). The latter three approaches may vary, depending on whether or not the plant is transferred back to the municipality at the end of the contract.

Outside of new project builds, engineering, procurement, and construction firms (EPC firms) and consulting firms also play large roles in the event of EPA consent decrees. Consent decrees are a regulatory tool used by EPA to take legal action against large polluters, and they often require plants to upgrade or expand their facility to bring them back into regulatory compliance. In order to do this, municipalities typically engage the same firms they turned to for project development. As such, the value chain can be depicted as follows:

Examples of Entities in Current US Water Market



Examples of major EPC firms in the US with a significant water focus include AECOM, Black & Veatch, CDM, CH2M Hill, MWH, Tetra Tech, and URS. These firms have a major water market share in the US, but they also diversify their focus to other sectors (transportation, power, etc.). There are, however, a few firms that primarily focus their services to the water market, including Aquatech, Carollo, Caldwell, Hazen & Sawyer, and Malcolm Pirnie. Profiles of some of these companies are presented below:

- **Black & Veatch** is a global engineering, consulting, and construction company specializing in infrastructure development in water, energy, telecommunications, and other environmental markets. The employee-owned company has more than 100 offices located around the globe. The firm estimates that ~20% of the world's population served by community systems currently accesses potable water through systems that were designed, constructed, or supported by Black & Veatch.

- **CH2M Hill** is a global consulting, design, design-build, operations, and program management firm. Its core focus areas include water, transportation, environmental, energy, facilities, and resources. The Colorado-based firm has been gradually increasing its water presence overseas, with an estimated 70% of revenues coming from international markets in 2011. The firm also has an operations and maintenance arm called CH2M Hill OMI, which allows the firm to participate in DBO projects. In total, CH2M Hill has a global workforce of over 23,000 employees.

- **MWH** is a provider of consulting management, engineering and technical services, and construction management services mostly relating to wet infrastructure. Other focus areas include hydropower, mining, transportation, and energy, but the company claims that over 50% of its work is in water and wastewater. Located in Broomfield, Colorado, the firm maintains a global presence through 180 offices in 35 countries.

- **Aquatech** offers global sourcing, EPC, Operations & Maintenance (O&M), and other onsite services to clients around the world, and has the ability to deliver projects on a BOOT basis. The company also provides a full spectrum of water treatment technologies for industrial and infrastructure markets, with a focus on desalination, water reuse, and zero liquid discharge. Gradually, however, Aquatech has changed its strategy to move up the value chain into plant operations and ownership. Its subsidiary, Aquatech Eastern, focuses on providing water solutions in the Middle East and Asia-Pacific.

- **Carollo Engineers** specializes in the planning, design, and construction of water and wastewater facilities around the US, with 32 offices in 12 states. The firm delivers projects via the traditional DBB method, in addition to the DB and DBO methods, and also assists with obtaining necessary permitting and any grants or incentives that are available.

There are also some global firms that play a large role in shaping the US water sector. Key firms include Veolia Environnement and Suez, both of which are profiled below.

- **Veolia Environnement** is one of the world's largest providers of diversified environmental services. The firm, headquartered in France, is primarily engaged in operating various municipal water, waste, energy, and transportation systems. Roughly 70% of the company's business comes through municipal contracts, with the remaining percentage through industrial/corporate relationships. The company has over 300,000 employees operating in 70+ countries and principally provides labor and management services to these industries.

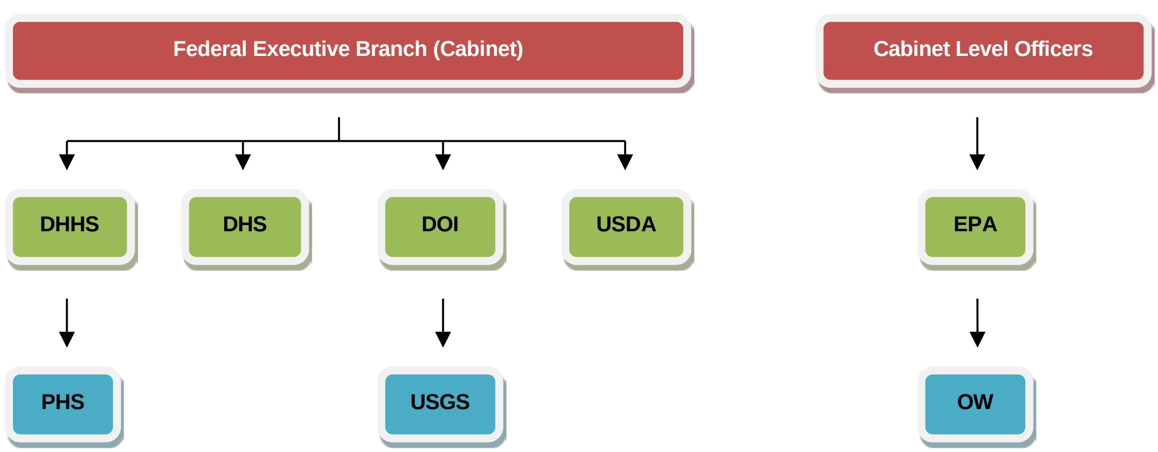
- **Suez Environnement** is a global operator that, through its subsidiary SUFEGE, has claimed a large role in wet infrastructure development. The firm has four core businesses including water and hydraulic infrastructures, environment and waste, urban and transport infrastructures, and energy. Suez focuses on offering comprehensive solutions that can be applied across the entire value chain for water and waste. Through its various subsidiaries around the world, Suez has pursued a selective development strategy that is based on local partnerships.

2.5 Regulatory Structure and History

Common across all of our surveyed sectors (and indeed across all of water), is the central role regulation plays in motivating (or deterring) the development of new technologies. In repeated interviews, we heard of technical achievements in search of a market need. As an example, despite the availability of extremely accurate fluoride testing technologies that may serve many benefits, utilities often cannot justify purchasing such technology when there are already systems that allow them to meet the existing regulatory standard around the presence of fluoride. Should that standard be lowered, a new market will be borne. Indeed, this high sensitivity to regulation is often shared by many investors and entrepreneurs who choose to pass on opportunities in water. To delve deeper into how regulation can impact innovation in the water sector, we start with a brief background.

At the national level, the US Environmental Protection Agency (EPA) is the primary body tasked with regulating water and wastewater. There are 10 regional EPA offices that are responsible for overseeing and enforcing water programs within specific territories. Each region has at least one environmental agency that administers regulations at the local level.   Within EPA, the Office of Water (OW) is mandated to ensure the safety of drinking water, protect human health and maintain the oceans, watersheds, and aquatic ecosystems. The OW works with regional EPA offices, other federal agencies (see below) and state and local governments to implement environmental acts and statutes.

Alongside EPA, several other ministries and departments touch water.   The US Department of Agriculture (USDA) develops regulations and directives for the agricultural industry, such as the use of pesticides and chemicals in the manufacture of food and wastewater discharge from agricultural processing.   The Department of Health and Human Services (DHHS) works closely with the Public Health Service (PHS) to provide legislation and guidance on health issues from water contaminants. The Department of Homeland Security (DHS) regulates and enforces rules relating to critical water infrastructure that is either demarcated as being at risk of terrorism or vulnerable to natural disasters. The US Geological Survey (USGS), a Department of Interior (DOI) agency, responds to major events that affect the quality of water resources. The graphic below shows the relationships between these various entities.



In addition to this federal level regulation, each state has its own health and environmental protection departments that regulate water and wastewater. Under constitutional and federal law, state regulations must meet the national standards set forth by EPA, but individual states are able to increase these standards as they see fit. Some states delegate enforcement powers to EPA, while other states administer programs under their own jurisdiction or in conjunction with EPA.

Turning to legislation, there are two foundational acts that regulate water at the federal level: the Clean Water Act (CWA) which covers all source water, and the Safe Drinking Water Act (SDWA), which authorizes standards for drinking water. Both are described in more detail below:

The basis for the CWA comes from the Federal Water Pollution Control Act of 1948, which was later reorganized and expanded to become the CWA. The CWA establishes the basic structure for regulating the discharge of pollutants from point sources (i.e., industrial and agricultural facilities) into US waters and regulating quality standards for surface waters. Although the CWA does not deal directly with groundwater or with water quantity issues, it employs a variety of regulatory and non-regulatory tools to sharply reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Requirements for point source discharges are based on the performance of available pollution control technologies (subject to a cost-benefit analysis), without regard to the conditions of a particular receiving body of water.

Existing methods of testing surface water quality, however, can be arbitrary in nature. For example, biochemical oxygen demand (BOD) is regularly monitored to ensure aquatic life and aesthetic quality of lakes and streams can be maintained. The testing period to determine BOD levels (5 days at 20^{o}C) was formed from the BOD test defined by the UK Royal Commission on Sewage Disposal in the 19th century, which referenced the maximum amount of time it takes for river water to travel from source to estuary in Great Britain in the region’s average summer climate. To change this test, which currently has no theoretical grounding, would also mean changing the equipment and supplies used in the test.

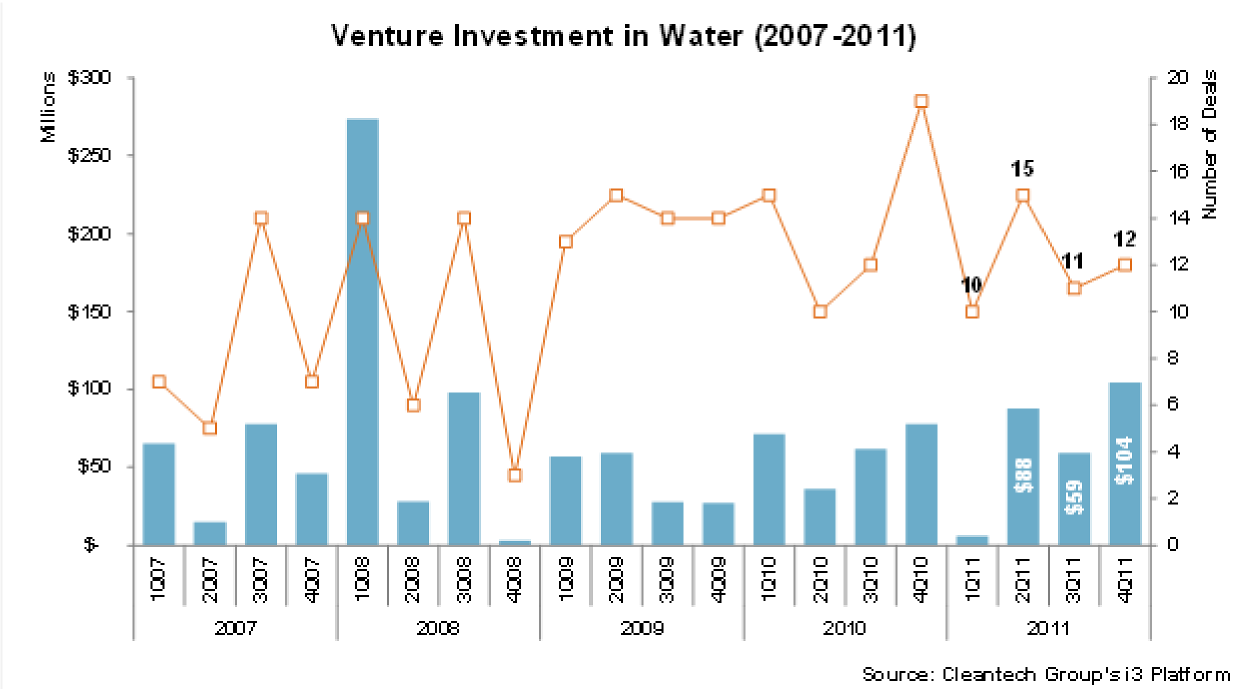
The SDWA was adopted in 1974, when improvements in water testing allowed for the detection of smaller concentrations of contaminants, resulting in organic contamination being discovered in public drinking water. Congress was then persuaded to take action and develop the first federally enforceable drinking water regulation.

Under the SDWA, EPA is required to set national health-based standards for drinking water to protect against both naturally occurring and manmade contaminants that may be found in drinking water. These standards, known as the National Primary Drinking Water Regulations (NPDWR), set both a maximum contaminant level goal (which is unenforceable) and a maximum contaminant level (which is enforceable). At least every six years, EPA must review these standards and make any necessary updates based on the latest health data/reports and the ability of the best available technology to attain the specific water quality standards. Underneath this federal legislation, each state may set and implement its own drinking water contamination regulations, with the caveat that these standards be no less stringent than those set by EPA. For example, California regulates the presence of aluminum in drinking water while the NPDWR do not.

According to several vendor interviews, the current regulatory structure is too compartmentalized and creates artificial boundaries where a unified approach to water resource management ought to exist. Not only must vendors navigate regulation at the national, EPA level, but also at the state level, where regulatory policies may differ greatly. Better coordination and clarity seems a frequent request from the commercial community.

2.6 Investment activity in water innovation

Venture capitalists are increasingly looking to water for investment opportunities, though it still remains a niche sector for venture funds. In 2011, venture capital (VC) in water and wastewater grew 4.3% increase to $258 million (via 48 deals), up from $247 million (via 56 deals) in 2010. While the growing trend is encouraging, to put in context, this level of investment represented approximately 3% of total cleantech VC dollars in 2011, which is consistent with levels seen in the past. Focusing on the fourth quarter alone, we observed VC investment grow to $104 million (via 12 deals), which accounted for 4.7% of all cleantech VC investments – an encouraging statistic.



While water is increasingly a topic of interest in our discussions with venture capitalists—and we see this trend accelerating in the next few years—for most, water has traditionally not been a core focus (nor an area of internal expertise). Further, of the few VCs focused on the sector, few will invest in a water deal unless there is meaningful revenue history. Both XPV and Emerald Technology Ventures have stated so publicly. New to the space, VCs are less willing to take on much technology, market, and most importantly, regulatory risk, feeling that it is better to bet on a company that already has a product and customers, and just needs help to scale.

The story is notably different in the M&A market, where 2011 was a watershed year. The number of M&A deals increased from 37 to 56, and the total transaction value (based on disclosed amounts) went from $925 million to exceed $16 billion. This significant growth is partially explained by two landmark acquisitions that alone totaled $12.2 billion (Ecolab bought Nalco Holdings for $8.3 billion and Cheung Kong Infrastructure bought Northumbrian Water Group for $3.9 billion). Another notable transaction was BASF's acquisition of Inge Watertechnologies. Although the purchase price for this transaction was undisclosed, the deal came on the heels of Pentair's $705 million acquisition of Norit Clean Process Technologies and helped call attention to the membrane technologies industry.

Finally, seven water companies went public in 2011, raising $293 million or 2.9% of total cleantech IPOs. In comparison, 2010 water IPOs totaled $1.7 billion. The unusually strong 2010 year was on account of 6 IPOs in Asia totaling $1.5 billion. For 2011, Asian water companies raised only $105 million, on par with the $111 million raised by water companies in North America in 2011. Notable 2011 IPOs include Waterlogic International's listing on the Alternative Investment Market in London (for a $78 million raise) and Global Water Resources' listing on the Toronto Stock Exchange in Canada (for a $61 million raise).

3 Filtration

Water filtration is the process of removing particles too small to have been caught and removed in initial coagulation or sedimentation phases of drinking water treatment. Common water filtration methods include sand and/or pebble filters, granular activated carbon, and ion exchange media. The most innovative filtration methods today, however, use membrane technologies. An overview of key water filtration market drivers and challenges are highlighted below:

Drivers	• Social driver – public concern over ingesting chemically-treated water • Regulatory driver – strict turbidity and disinfection requirements set by EPA in surface water treatment rules • Economic driver – improved energy efficiency of new membrane technologies has brought down operating costs
Challenges	• Social challenge – lack of public education/trust on effectiveness of membrane technologies (e.g., skepticism over "toilet to tap" drinking water) • Regulatory challenge – stringent regulations around disposal of concentrated brine

3.1 Market

The overall US filtration market, including equipment and services, is estimated at approximately $2.2 billion in 2011, growing rapidly at 8.1% CAGR to reach $3.2B in 2016.[8] This sizing includes an estimated $1.1B in equipment, including membranes, media filtration, and ion-exchange systems. Related services include design engineering support, system operations, and system maintenance services (e.g., membrane fouling and replacement) typically average 0.75-1.25x of the overall equipment contracts, or alternatively an additional $830M-$1,380M to the total market (or overall sizing take the average).

Much of the growth is being fueled by innovation and increased adoption of membrane technology. This increase is being fueled by two key factors: First, costs of ownership have declined due to technical advances in design (e.g., higher efficiencies have led new membranes to have lower energy and other operational costs). Second, growing distrust of chemical use has caused a broader shift to non-chemical alternatives, such as membranes.

Barriers to market growth include the public's lack of education on the science behind membrane treatment processes. This is typically the root cause of negative public perceptions over applications like "toilet-to-tap" drinking water (wastewater that is treated for reuse as potable water), which relies heavily on membrane technologies. Also, regulations surrounding the disposal of concentrated brine—a waste byproduct of membrane treatment that can be damaging to the environment—pose a challenge to utilities using the technology.

Globally, sand filtration is most often the preferred technology in developing countries. Membranes, however, are gaining the most popularity particularly due to their use within the desalination process, which is big in the Middle East and Australia. Thermal desalination is an attractive option in the Middle East, where energy costs are low, but countries like Australia rely heavily on membrane technologies. Strict environmental standards result in complex water intake and discharge, however, making the desalination process an expensive one, which limits

[8] *Water Market USA 2011* (GWI 2010)

growth of the membrane market in that region. As a result, Australia (and other countries, like Singapore) will continue to explore alternatives to traditional water resources, and water reuse trends will ensure the membrane market continues to grow.

3.2 Policy and Regulation

Water filtration technologies are often used to meet turbidity and microbial log removal requirements set by EPA in surface water treatment rules. Microfiltration (MF) and ultrafiltration (UF) membranes, in particular, have demonstrated the ability to reduce turbidity to less than 0.1 NTU (nephelometric turbidity units), as well as remove Giardia and Cryptosporidium.[9] Water treatment rules include Surface Water Treatment Rule, Interim Enhanced Surface Water Treatment Rule, and the Long Term 1 and 2 Enhanced Surface Water Treatment Rules. These rules often create higher standards for filtration, as surface water or groundwater that is under the direct influence of surface water (GWUDI) are more vulnerable to microbial contamination.

The aforementioned surface water treatment rules are introduced below:

- The **Surface Water Treatment Rule** applies to all public water systems that use surface water or GWUDI, and includes treatment technique requirements to protect against adverse health effects associated with the presence of pathogenic organisms in drinking water supply. Plants using filters must meet combined filter effluent turbidity performance standards of 5 NTU as a maximum and 0.5 NTU at the 95^{th} percentile on a monthly basis, calculated using 4-hour monitoring data.

- The **Interim Enhanced Surface Water Treatment Rule**, which was finalized in December 1998, applies only to those public water systems that use surface water or GWUDI and serve populations of 100,000 or more. The regulation is meant to improve the control of microbial pathogens, and addresses risk tradeoffs between the presence of pathogens and disinfection byproducts. Disinfection byproducts are the chemical compounds that

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[9] EPA. "Low-Pressure Membrane Filtration for Pathogen Removal: Application, Implementation, and Regulatory Issues". April 2001.
http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/report_lt2_membranefiltration.pdf

form as a result of disinfectants reacting with naturally present compounds in source waters. The rule reduces combined filter effluent turbidity performance standards to 1 NTU as a maximum and 0.3 NTU at the 95^{th} percentile on a monthly basis, calculated using 4-hour monitoring data. Individual filter turbidity monitoring requirements were also introduced, which include the submission of an "exceptions report" to the state agency on a monthly basis.

- The **Long Term 1 Enhanced Surface Water Treatment Rule** was proposed in April 2000, and extends the requirements of the Interim Enhanced Surface Water Treatment Rule to public water systems that use surface water or GWUDI and serve fewer than 10,000 people.

- The **Long Term 2 Enhanced Surface Water Treatment Rule**, published in 2006, builds on earlier rules and is targeted towards reduction of illness associated with Cryptosporidium and other pathogenic microorganisms. This rule requires monthly monitoring of systems (via monthly sampling for Cryptosporidium) for an initial two year period, followed by a second round of monitoring six years after completion of initial testing. Currently, regulations require 2-log removal of Cryptosporidium for filtered water systems, and up to 3-log removal for unfiltered water systems. Additionally, systems that access open reservoirs must treat water to inactivate 4-log virus, 3-log Giardia lamblia, and 2-log Cryptosporidium.

EPA also sets specific legal limits on the levels of certain contaminants in drinking water, under the jurisdiction of Safe Drinking Water Act. These limits are determined based upon levels needed to protect human health and that are considered achievable by water systems using the best available technology. Arsenic, for example, is an odorless and tasteless semi-metal that is known to cause skin damage or problems with circulatory systems, and may increase the risk of getting cancer. Given the element's natural occurrence in the environment (presence in rocks and soil, air, plants and animals), EPA monitors arsenic levels in drinking water. In 2001, acceptable arsenic levels were reduced from 50 parts per billion (ppb) to 10 ppb.[10] This prompted many water systems to seek and test a variety of new treatment technologies for effectiveness and affordability. One water system—the Fallon-Paiute-Shoshone water system in Nevada—tested both a pressure filtration and a coagulation/microfiltration system, and determined the latter option was more cost-effective and suitable for their arsenic levels. Another water system, the Coldwater Canyon Water Company in Arizona, began using Dow Chemical Company's ADSORBIA granular titanium oxide after a full-scale pilot test. While the EPA limits can sometimes be seen as an encumbrance to water systems due to the high capital and operating costs often associated with treatment technologies (according to one major water utility in Arizona), the standards clearly foster growth in advanced water filtration and disinfection systems while also promoting safer drinking water.

3.3 Technologies

3.3.1 Products

As previously mentioned, membranes are the most common filtration techniques used in the drinking water treatment process, and are becoming more so as costs go down and efficiencies go up. Other filtration methods include sand/pebble filtration, granular activated carbon (GAC), and ion exchange media.

Membranes: Membranes are thin sheets of material that act as a physical barrier to suspended or colloidal particles present in source waters. They were first developed in 1965 for the desalination market. These membranes—reverse osmosis membranes—fundamentally disrupted the thermal desalination market and quickly became the leading method for removing dissolved solids from water. Thermal desalination processes apply significant amounts of heat to high salinity water to create water vapor, which is then condensed to form high-purity distilled water. The particular advantage of membrane separation processes was that they operated without this requirement for heat, and thus consumed less energy than conventional thermal

[10] EPA. "Arsenic in Drinking Water". <http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/index.cfm>

separation processes (distillation, sublimation, or crystallization). Over time, membrane efficiencies have continued to improve, and the economics of operating membrane plants over thermal plants has caused membrane technology to increase its market share.

Membrane treatment technologies are typically classified according to the size of the molecules that they are able to filter (which is dependent on membrane pore size), and fall into two broad categories: *pressure-driven* and *concentration-driven*. Pressure-driven processes depend on water pressure as the driving force to separate particles based on size, and include reverse osmosis, nanofiltration, ultrafiltration, and microfiltration membranes. In contrast, concentration-driven processes like forward osmosis use a concentrated solution to draw water through a membrane, effectively trading the solutes of one solution for another. Processes like forward osmosis have typically been reserved for desalination and evaporative cooling tower make-up water, but are slowly being introduced to drinking water systems. Key membrane technologies are highlighted below.

- **Reverse Osmosis (RO):** As previously discussed, RO membranes were first introduced in 1965 as a lower cost method of treating seawater. The membranes are dense sheets of material that technically do not have pores, thus allowing for the removal of nearly all inorganic compounds and organic molecules. Membranes are typically found in a spiral-wound arrangement in which layers of flat membrane sheets are rolled around a central pipe that provides the water to be treated. Due to membrane fouling and the threat of limiting membrane efficiency, water is nearly always pretreated to remove contaminants. The brine, or highly concentrated residual solution once the RO process is complete, must be disposed of carefully, as it may be detrimental to surrounding marine life and plants. Innovation regarding RO membranes has focused on improving energy efficiency, but the laws of thermodynamics require a minimum of 0.8 kWh/m3 of energy and have been somewhat limiting. Currently, the best performing RO membranes utilize between 3.8 –

4.2 kWh/ m3.[11] One industry expert estimates there is still room for about 20% improvement in membrane efficiency before hitting a plateau.

- **Microfiltration (MF)/ Ultrafiltration (UF)/Nanofiltration (NF):** MF membranes have the largest pore size, and can remove sand, silt, clay, algae, bacteria, Giardia, and Cryptosporidium. UF membranes, with slightly smaller pore sizes, have the ability to remove everything an MF membrane can, in addition to viruses. NF membranes, as a result of having the smallest pore size, provide near complete protection against viruses and most organic contaminants. These membranes, which require very high water pressures to force water through to the other side, can also reduce hardness in water. Since the reverse osmosis breakthrough, there has been tremendous interest in encompassing the emergence of low pressure membranes like MF and UF in drinking water treatment, tertiary wastewater treatment, membrane bioreactors (MBR) and various industrial applications. In drinking water, the low pressure membranes are used to pretreat water before going through an RO membrane, as they reduce the amount of chemicals required to remove microorganisms and provide a guaranteed feedwater quality, which also helps to reduce membrane fouling and corrosion. In 2010, it is estimated that 4% of low pressure membranes were used in desalination, while 51% were used in MBR applications, 13% in tertiary wastewater treatment, 14% in industrial applications, and 18% in drinking water processes.[12] Sales of low pressure membranes for RO pretreatment processes are expected to increase from $45 million in 2011 to $130 million in 2016.[13]

- **Forward Osmosis (FO):** A recent spate of membrane innovation has introduced FO processes. Like RO, FO is a membrane-based separation process that removes dissolved solutes from a solution, but does so without requiring pumping of energy, resulting in low energy consumption. FO and its variations in hybrid systems are projected to be promising technologies that could have broad applications to desalination, brine disposal

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[11] *Water Technology Markets 2010* (GWI 2009).
[12] *Water Technology Markets 2010* (GWI 2009).
[13] *Water Technology Markets 2010* (GWI 2009).

and water treatment markets. However, the biggest obstacle to the commercialization of FO technology is the lack of commercially available FO membranes, with existing FO systems utilizing RO membranes that have been adapted to the FO process. However, these suffer from inherent operational limitations in FO systems. Widespread commercialization of FO membranes is not expected to be achieved for another 3-5 years.

The next big wave of innovation in the membrane market is expected to focus on continued efficiency improvements of existing membranes, rather than the introduction of entirely new membrane processes. Innovators are increasingly concerned with developing more efficient membrane filtration methods that not only control pathogens and filter a diversity of contaminants, but do so utilizing less energy and creating fewer byproducts or waste. As the largest impediment to the widespread adoption of membrane technologies, high energy requirements will be a core focus of innovators, and energy costs are predicted to fall over the next 5-10 years.

Sand filtration: Sand filters, which have existed since the early 1800's, are very effective in treating surface water and removing viruses (e.g., Giardia) and coliform bacteria by up to 99%. They can vary in size (i.e., length, depth) based on desired flow rate at a treatment plant. Slow sand filtration works by passing water through a thin layer of biofilm at the top of the sand. This gelatinous layer is typically made up of bacteria, fungi, protozoa, and a range of aquatic insect larvae, and is what ultimately provides the purification of the water. The underlying sand serves primarily as a support medium for this top layer. The simplicity of this technology—as it requires no mechanical power, chemicals, or replaceable parts, and only minimal operator training—makes it an attractive and logical solution for poor and isolated areas. However, for large municipalities, extensive land area must be available to house the slow sand filtration system. Another potential disadvantage of this filtration method is that slow sand filters are most efficient with low turbidity water, which means pretreatment may be required in hot summer months or when raw water is turbid. Despite having been studied extensively by scientists, a complete understanding of the biological activity that occurs within sand filtration does not yet exist, making innovation in this area difficult.

Rapid sand filtration, on the other hand, is a physical process that requires a smaller land area, less sand, and passes water at a much higher flow rate (up to 20 meters per hour[14]). Further, the system is less sensitive to changes in raw water quality (e.g., turbidity). However, these systems require the use of chemicals and greater maintenance (cleaning once or twice daily), making them more costly.

Granular activated carbon (GAC): GAC is one of the most commonly used media for adsorption—a process in which molecules from dissolved compounds collect on and adhere to an adsorbent solid—within the drinking water treatment process. Water is passed through a stationary bed of activated carbon, leaving organic materials to accumulate at the top of the bed, and filtered water to move on to the next phase of water treatment. The technology, made up of tiny clusters of carbon atoms stacked upon one another, is produced by heating a carbon source (e.g., coal, wood, peat) in the absence of air. GAC is a particularly good adsorbent given its high surface area to volume ratio (one gram typically has a surface area of 1,000 square meters[15]), which permits the adsorption of a large number of contaminant molecules, and the subsequent removal of toxic organic compounds to virtually non-detectable levels. For this reason, GAC is an EPA Best Available Technology Economically Achievable (BAT)[16] for disinfection byproducts, mercury and cadmium, natural organic matter, certain synthetic organic chemicals, and radionuclides. While this technology is sometimes considered to be one of the least expensive treatment options, it is important to note that filters must be cleaned and/or replaced on a regular basis. Additionally, there exists the possibility that GAC filtration systems will adsorb nitrate during the water treatment process only to later release (at an unknown frequency) that nitrate into treated water. Certain California water systems faced this problem and were forced to make modifications to their GAC system or other parts of their water treatment process. For

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[14] WHO Seminar Pack for Drinking-Water Quality
<http://www.who.int/water_sanitation_health/dwq/S12.pdf>
[15] Carbtrol Corporation. *Granular Activated Carbon for Water & Wastewater Treatment*. September 1992.
[16] According to EPA, BAT is defined as: "…the best available economically achievable performance of plants in the industrial subcategory or category. The factors considered in assessing BAT include the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the process employed, potential process changes, non-water quality environmental impacts, including energy requirements and other such factors as the EPA Administrator deems appropriate."
<http://water.epa.gov/scitech/wastetech/guide/questions_index.cfm#bat>

example, in 2002, the California Department of Health Services directed "all water systems with GAC treatment systems to increase the nitrate monitoring frequency of the GAC effluent to at least one sample per week."[17]

An adsorbent that has been raising interest in the last few years is zero valent iron (ZVI), which has traditionally been used for groundwater remediation. The technology's ability to remove biological contaminants, such as viruses, from water was first cited by researchers in 2005.[18] Subsequently, it was shown that ZVI could also remove natural organic matter, which would help to prevent the formation of disinfection byproducts. ZVI can be added to filtration systems as another granular medium (along with sand or gravel), and is thought to be particularly effective as a pretreatment to chlorination. Liberty Hydrologic Systems, a West Virginia-based company, received seed funding from Meidlinger Partners to further the research and commercialization of its Generation 2 Selenium Remover ZVI solution.

Ion exchange: Ion exchange refers to processing water through ion exchange resins, which are typically bead-like and spherical in shape, where ions from the water are exchanged for ions fixed to the resins. The two most common forms of ion exchange are softening and deionization. Softening is often used as a pretreatment to the RO process, as water hardness can be reduced by exchanging two sodium ions for one calcium or magnesium ion. Deionization, a process in which hydrogen ions are exchanged for cations or hydroxyl ions are exchanged for anions, is often used in combination with RO filtration or carbon adsorption. This is because while ion exchange is effective at removing dissolved inorganics, it does not effectively remove chlorine or other organic contaminants in water. Also, while ion exchange requires a relatively inexpensive initial capital investment, operating costs over the long term can be high. A regular schedule of inspection and cleaning is necessary to help prevent resin fouling and degradation, one of the most common problems of using ion exchange systems.

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[17] http://www.safedrinkingwater.com/community/GAC_nitrate_letter_2.pdf

[18] Water Research Foundation. *Enhancing Removal of Viruses in Water Treatment Plants Using ZeroValent Iron [Project #4140]*. July 2011.

Since ion exchange materials were first introduced to water treatment in 1906, there have been vast improvements in ion exchange materials. The process first used natural and synthetic inorganic products, but further research has led to the development of sulfonated coal, styrene-base resins, phenolic resins and acrylic resins.[19] New materials continue to be explored for increased exchange capacities.

3.3.2 Services

Often, some degree of source water-specific testing is necessary to determine effectiveness of water filtration systems before they are installed at full-scale. For example, it is important to confirm GAC systems have the ability to adsorb target contaminants in the raw source water, or to understand what filtered water turbidity an operating sand filter will attain. While these tests need not be expensive, they will require the assistance of an EPC firm.

Maintenance and cleaning of the water filtration systems can often be conducted by the treatment plant's own employees, or by a contracted EPC firm. With the exception of membrane systems, cleaning components of a water filtration system can be simple, but time consuming. Sand filtration systems require backwashing (reversing the direction of the water flow) or, in the case of slow sand filtration, a scraping of the top biological layer once it gets near 2cm in thickness.

While not all water treatment plants currently use membranes for drinking water treatment (e.g., Greater Cincinnati Water Works uses sand filtration and GAC treatment, followed by disinfection), membrane technologies are increasingly becoming key components of the treatment process. RO membranes have been standardized in RO systems, and as a result, have become somewhat commoditized. The variety of low pressure membranes available, however, indicates that these suppliers have a higher level of involvement with treatment plants than RO membrane manufacturers. Either the membranes are sold as whole systems, requiring no additional support from the supplier, or sold as individual membranes, in which case a supplier

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[19] Nalco. *Ion exchange processes*. <http://www.onlinewatertreatment.com/literature/Nalco/docs/Tf-024.pdf>

must provide engineering support to ensure that system configurations comply with membrane warranties. Since membrane technologies are components of treatment subsystems within larger plants, the business model employed by a number of market participants concentrates not only on the optimization of the membrane equipment, but also on the entire subsystem.

The distinction between components and systems means that EPC (Engineering-Procurement-Construction) service firms compete with one another to buy the same parts from the same suppliers. As the margins for designing and building membrane treatment plants become increasingly narrow, EPCs are broadening their role by providing operations assistance to utilities or working with a project developer to take an equity share in the project. While there is some scope to employ process engineering to deliver water at a lower cost, this is a not a patentable proposition, which leads to EPCs gaining only a short-term edge in terms of cost.

3.4 Vendor landscape

The majority of US water filtration companies are located in California, including companies like NanoH2O, Pionetics, and M2 Renewables. Texas houses the next highest number of water filtration companies, including Water Standard and Envirogen Technologies.

While there is significant innovation, the membrane market is mature and increasingly commoditized. Market leaders are typically early movers who establish share and a brand for quality early on. One of the biggest barriers to entry is the relatively conservative environment in this arena, which places higher importance on US-based proven applications versus international applications. While globalization is expected to dissolve this barrier in the long term, foreign players currently experience difficulty in gaining market acceptance when entering the US market. Globally, the leading RO membrane suppliers include Dow Water & Process Solutions, Hydranautics, Toray, Koch Membrane Systems, CSM, and Toyobo. The leading low pressure membrane suppliers include Siemens, Pall, Norit Clean Process Technologies (acquired by Pentair), Metawater, and Inge (acquired by BASF).

3.5 Venture activity

Global venture activity in water filtration dropped 37% in 2011 to $61.2 million from 2010's $96.4 million. The large majority of investments have supported companies in the membrane space. Traditionally, these companies have relied on growing organically through proving the reliability of their membrane solutions and building a trusted brand. Securing enough capital to carry out these activities can be tough for new entrants. For instance, Bio Pure Technology, an Israeli company, successfully completed two rounds of financing in 2007 and 2009, but announced liquidation in November 2011. The company was backed by Silicon Valley-based US Venture Partners, Israeli venture capital firm Pitango and Tel Aviv-listed technology holding company Elron. Its main products, NF membranes and a hybrid membrane treatment system, were both intended to treat highly contaminated wastewater from mines, agro-chemicals production, and other industries. Without additional funding to help bring products through testing and commercialization however, the company soon found itself seeking investors to buy its assets.

As demonstrated by the example above, one of the primary keys to the success of any membrane technology company is the ability to build a list of referenceable clients, which requires increasing customer access and working capital. Both of these are significant challenges for vendors without ready access to growth capital. An attractive solution to this dilemma is merging with or acquiring a competitor, a trend we have noticed has been increasingly popular in recent years.

In 2011, Inge Watertechnologies was acquired by BASF, a German chemical giant, for an undisclosed sum. This move is expected to help Inge increase market share through increased stability, re-established market focus, and deep pockets. Additional recent consolidation in the membrane market includes Pentair's 2011 acquisition of Norit Clean Process Technologies for $705 million, which demonstrated Pentair's desire to increase its presence in fast growth markets like Latin America and China, where Norit is a strong player (only 15% of Norit's 2010 revenue was from Eastern Europe and USA regions, with the remainder coming from international markets).

The venture capital funding raised by various filtration companies—most of whom focus on membrane technologies—during the 2009-2011 period can be seen in the following chart.

Company	Country	Description	Capital raise	Round
NanoH2O	USA	Developer of thin-film nanocomposite membranes ideally suited for sea water reverse osmosis desalination plants.	$40,000,000 $14,872,599 $10,000,000	Series E+ Series D Series C
Shenzhen JeCh Technology	China	Developer of proprietary membrane suited for municipal water and wastewater treatment.	$30,800,000	Series A
ItN Nanovation	Germany	Manufacturer of nanoparticles that are then processed into high-tech ceramics for filtration systems, catalysts and protective coatings.	$20,000,000	Growth Equity
Triton Water	Singapore	Assembles and installs water treatment modules ranging from low-energy desalination, to water management and wastewater systems.	Undisclosed $15,000,000	Series B Series A
Bio Pure Technology (BPT)	Israel	Developer of nano filtration membranes and systems for waste water treatment.	$12,000,000	Series B
HaloSource	USA	Developer of antimicrobial coated filter cartridge and other drinking, recreational, and environmental water treatment products.	$10,000,000	Growth Equity
Oasys Water	USA	Developer of a forward osmosis platform for desalination, water treatment, and waste heat recovery.	Undisclosed $10,000,000	Series B Series A
Inge AG	Germany	Developer of ultrafiltration membranes and modules for the treatment of drinking water.	$6,958,000	Series C
NEP Holdings	Malaysia	Developer and distributor of water filtration systems that utilize ceramic beads.	$5,000,000	Series A
Waterlife India	India	Developer of technology for water purification.	$4,163,907	Series A
Clean Filtration Technologies	USA	Developer of a self-cleaning, maintenance-free metal membrane used to process wastewater and produce clean, drinking water.	$3,500,000	Series B
Likuid Nanotek	Spain	Developer of inorganic membranes for filtration processes.	$2,700,000	Growth Equity
ABSMaterials	USA	Developer of a reactive glass that swells up and absorbs impurities from water.	$2,400,000 $250,000	Series A Seed
M2 Renewables	USA	Developer of filtration process to obtain irrigation-quality, reusable water directly from raw sewage.	$2,500,000	Growth Equity
Axium Nanofibers	USA	Developer of air and water filter products using nanofiber technologies.	$2,300,000	Series A
AquaZ	Denmark	Developer of an aquaporin membrane technology for water purification.	$1,050,000 Undisclosed	Series A Seed
RC-lux	France	Developer of point-of-use water filtration systems that utilize hydrodynamic cavitation and UV treatment.	$1,195,796	Series A
nano-porous solutions	UK	Developers of multi-layer adsorbent hollow fibre material used in water separation and filtration processes.	$1,170,000	Seed
Advanced Hydro	USA	Developer of a technology to reduce membrane fouling using a deposition technique to adhere Polydopamine onto the surface of commercial membranes.	$500,000	Seed
Liberty Hydrologic Systems	USA	Developer of proprietary zero valent iron technology to remove selenium from water.	$500,000	Seed

3.6 Company Profiles

For profiling purposes, recently funded US-based membrane technology vendors from various sectors of the membrane market were selected.

- Porifera
- Oasys
- NanoH2O

4 Disinfection

Disinfection is primarily used in the latter phases of the drinking water treatment process. Disinfection agents range from *chemical* disinfectants, such as hypochlorite, chloramines, or ozone, to *physical* disinfectants, such as ultraviolet (UV), electronic radiation, or heat. Key market drivers and challenges are highlighted below:

Drivers	• Economic driver – applicability of certain disinfection solutions (e.g., UV) make it an attractive investment for facilities treating water to multiple levels • Regulatory driver – stringent limits on disinfection byproducts
Challenges	• Economic challenge – relative affordability and accessibility of chlorine make it an attractive disinfection treatment • Market challenge – costly and time-intensive processes associated with being approved and selected as a technology provider

4.1 Market

Excluding chemicals (to maintain a focus on areas of equipment innovation), we estimate a total market size of both equipment and related services of $2.25 billion in 2011, growing at 6.4% CAGR to top $3 billion by 2016. [20] Equipment comprises $640 million of the total market, though the majority remainder is made up of services, which is estimated at 2-3x equipment sales

[20] *Water Market USA 2011* (GWI, 2010)

(or $1.3-1.9 billion in 2011).[21] This multiple is broad given the numerous attendant services needed. In addition to the EPC services provided by contracted firms, the disinfection contracts typically include chemical delivery and storage costs, control systems (i.e., computational fluid dynamics), and lamp replacements.

One reason for the market growth here is that disinfection technologies have numerous applications. Not only is disinfection the key aspect of treatment for drinking water applications, it is equally important in myriad industrial process water and wastewater, as well as municipal wastewater applications. The ability to treat water to various levels based on a combination of disinfection solutions poses a significant economic benefit to utilities concerned with tightening water quality regulations. Also, disinfection solutions are increasingly addressing the problem of disinfection byproducts, which are now heavily regulated. Disinfection byproducts are the chemical compounds that form as a result of disinfectants reacting with naturally present compounds in source waters.

Barriers to market growth, however, include the cost and availability of the new disinfection solutions. Since the discovery of disinfection byproducts, utilities have been forced to invest in additional technologies that remove disinfection byproducts or to adopt entirely new disinfection processes. However, chlorine is still one of the most commonly used disinfectants, and will continue to be so due to its relative affordability and accessibility. While innovative disinfection solutions exist, equipment vendors are not able to supply these alternate solutions as easily as they had hoped, due to costly and time-intensive regulatory processes required to be approved and selected as a technology provider.

Certain disinfection technologies are becoming increasingly attractive in international markets. UV and advanced oxidation processes, for example, are coveted solutions in countries like Singapore and Australia that are rapidly expanding their water reuse efforts. Chemicals used for disinfection are also increasingly desired, and are facing an increased amount of competition in the US from global competitors. One industry expert noted that Chinese companies are offering

[21] Industry interviews; Cleantech Group Analysis

chemical disinfectants for a fraction of the price of US providers, but that the lower price may be associated with lower quality.

4.2 Policy and Regulation

In the seventies, scientists discovered the possible production of disinfection byproducts, such as trihalomethanes, haloacetic acids, bromate, and chlorite, when treating water with chlorine or other disinfectants. This discovery eventually led to the December 1998 establishment of the Stage 1 Disinfectants/Disinfection Byproducts Rule, which aims to reduce the public's exposure to disinfection byproducts in public water systems. The rule requires any public water system that adds disinfectants during the water treatment process to implement additional treatment measures to reduce the formation of disinfection byproducts and achieve specific contaminant standards. Because of this new rule, water treatment facilities began searching for alternative treatment methods that did not involve chemicals. The UV market in particular benefited from the new legislation, and is expected to experience additional growth as a result of the Long Term 2 Enhanced Surface Water Treatment Rule, in which UV is listed as an option for municipalities to comply with additional treatment requirements (see Section 3.2 for additional information). Within LT2ESWTR, there are several requirements that address UV dosing, performance validation testing, monitoring, reporting, and off-specification operation.

In the 1990s, the discovery of and introduction to endocrine disrupting compounds (EDCs) also opened the door for new regulations, and consequently, innovation with regards to disinfection solutions. EDCs are chemicals that interfere with endocrine systems to cause cancerous tumors, birth defects, or other developmental disorders. These chemicals have been found to enter water systems as byproducts or leachates, resulting in EPA amending the SDWA in 1996 to allow for the screening of substances that may be found in sources of drinking water for endocrine disruption potential.

Another crucial piece of legislation relating to the disinfection market is **the Ground Water Rule**, which was published in 2006. The rule, targeted to ground water systems that are susceptible to fecal contamination, has a goal of increasing protection against microbial pathogens. The basic requirements of this rule include sanitary surveys (every 3-5 years), source water monitoring, compliance monitoring, and/or corrective actions.

Disinfection technology certification processes can also influence the competitive landscape and available solutions. For example, UV disinfection initially experienced rapid growth after being listed as a Best Available Control Technology by EPA in August 2009, following the 1993 Cryptosporidium outbreak in Milwaukee, WI. The Best Available Technology (BAT) standards put forth by EPA played a critical role in the creation and growth of the UV disinfection market in the US. However, cost has been cited as one of the largest challenges in attaining EPA certification as a BAT, followed by long timelines.

4.3 Technologies

4.3.1 Products

Innovation in the disinfection sector not only focuses on controlling pathogens and producing fewer disinfection byproducts, but also on minimizing capital and operational costs. Key disinfection technologies are highlighted below.

Chlorine: Chlorine, which is relatively cheap and easy to produce, has long been the most widely applied disinfectant in the US, with about 90% of water utilities using it for disinfection.[22] However, the discovery of chlorinated byproducts, and subsequent regulation of these byproducts, has slowly led drinking water treatment plants to seek other alternatives. Many plants started adding chloramine, a disinfectant formed by mixing chlorine with ammonia, as a secondary disinfectant. In 2002, an estimated 20% of US drinking water facilities used chloramines,[23] and that number has since increased to nearly 33% of all public water systems in

[22] Chlorine: the Achilles Heel? Presentation at the 2009 American Water Works Security Congress, by John McNabb.

[23] Lenntech – a Netherlands-based developer, designer, and manufacturer of water treatment plants. http://www.lenntech.com/processes/disinfection/introduction/introduction-water-disinfection.htm

the US.[24] Chloramine is favored for its ability to produce a lower concentration of disinfection byproducts (with the formation of little to no trihalomethanes) and its ability to persist and remain active in water storage tanks for long periods of time. However, it has caused the formation of new disinfection byproducts such as N-nitrosodimethylamine (NDMA), which is leading to investigation. It is also known to be less effective than chlorine in the inactivation of E. Coli, and has the potential to cause corrosion of lead or copper water distribution pipes in the case of ammonia being released through chloramine's chemical interaction with water. These limitations of chloramine allow chlorine to still be one of the most trusted methods of eliminating water-borne pathogens and preventing reinfection during transport, storage, and distribution of treated water.

Ultraviolet (UV): Ultraviolet disinfection is the fastest growing disinfection alternative with a 15-20% growth rate in the municipal water and wastewater markets,[25] primarily because it has the key advantage of being a byproducts-free physical process with low chemical management costs and safety risks. UV disinfection exposes water to short wave ultraviolet light, which is absorbed into the nucleic acid of harmful microbes, thereby harming DNA structures and eliminating the possibility of reproduction. The treatment solution is far more effective than chlorine in eliminating parasites such as Cryptosporidium or Giardia. Since the 1993 Cryptosporidium outbreak in Milwaukee, and upon being listed as a Best Available Control Technology by EPA in August 2009, the UV market has exploded. The market is expected to continue to grow rapidly with new regulations and the emergence of combination disinfection methods (e.g., UV + ozonation).

Ozonation: Ozonation, the injection of ozone, is another powerful disinfectant used to treat drinking water. Ozone is a colorless and unstable gas that is generated by air discharge, electro analysis, and UV light radiation to kill bacteria and viruses. It is often touted for its ability to

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[24] Pennsylvania Department of Environmental Protection. http://www.portal.state.pa.us/portal/server.pt/community/public_drinking_water/10549/chloramine_in_drinking_water/553919#question5

[25] Siemens. http://www.water.siemens.com/en/products/chemical_feed_disinfection/ultraviolet_disinfection/Pages/trends-uv-water-industry.aspx

effectively eliminate pathogens and organic materials without creating byproducts, but its use is limited by its high energy consumption and operating cost.

Peracetic acid: Peracetic acid (also known as peroxyacetic acid) is a colorless liquid that is typically produced by a reaction between hydrogen peroxide and acetic acid. The solution poses a health and safety hazard in high concentrations, and is therefore typically produced and sold in 12-15% solutions. The biocide oxidizes the outer cell membranes of microorganisms through an electron transfer, and is particularly effective for deactivating viruses and spores. In fact, treatment plants have cited the effectiveness of peracetic acid to be comparable to that of chlorine, albeit at a much higher cost. While the solution also is gaining attention because it forms no disinfection byproducts, its ability to destroy endocrine disruptors has recently been called into question. Effectiveness is reportedly diminished in waters with higher pH and lower temperatures. For these reasons, the solution has not been widely adapted to drinking water treatment processes. Rather, it is more attractive for wastewater and combined sewer applications, where its low degradation rate makes it more appealing than chlorine (as intermittent rain only calls for intermittent use of the disinfectant). Further, peracetic acid negates the use of sodium hypochlorite disinfectant and associated sodium bisulfite, and therefore eliminates the issue of sodium ion byproducts. The cost effectiveness of peracetic acid over sodium hypochlorite is currently being researched. The disinfectant is believed to be more widely used in Europe than in the US.

Advanced oxidation (AO): Advanced oxidation is a process that relies on chemical oxidation to remove contaminants from water streams, and can be a combination of technologies (e.g., UV and ozonation). AO solutions have gained a significant amount of attention in recent years due to their ability to degrade endocrine disruptors and similar compounds. They generate highly reactive hydroxyl radical species, which are a powerful oxidant. The oxidants can result in complete oxidation and mineralization of organic contaminants and break them down to carbon dioxide, water and mineral acids. While the process has proven to be very effective in removing emerging contaminants, it is a costly disinfection alternative for drinking water treatment plants as it requires higher capital and operational costs due to the use of reagents and irradiation sources.

4.3.2 Services

The disinfection technologies deployed in water treatment plants are typically chosen in a joint effort by EPC firms and plant owners and operators, leading them to play a large role in promoting innovation or presenting major obstacles to deployment of new technologies. For instance, CH2MHill evaluates the viability of technology choices for new build facilities and wields significant influence in supplier selection, while asset owners and private asset operators, such as Veolia Water and United Water (Suez), are integral to the vetting and deployment of new technologies. These firms typically show a preference for legacy, proven technologies. An overview of these firms and services is offered in Section 2.2.

Other services related to water disinfection are sometimes necessary for monitoring and maintenance of disinfection and dosing systems. For example, Grundfos Pumps' subsidiary Grundfos Alldos offers technical support and training for the systems they deliver to clients. The company employs project engineers to work with clients during any phase of installation – from planning and layout to calculating operating costs to commissioning and maintenance of the system. Companies offer clients these in-house services to leverage their product expertise, but EPC firms can also be contracted.

4.4 Vendor Landscape

Just as there are a range of disinfection technologies that can be used to treat water, there are also a range of equipment vendors that serve the municipal/utility market. In the North American chemical disinfection space, key vendors include Nalco (recently acquired by Ecolab), Chemtreat (a Danaher company), and Calgon Carbon Corporation. Within UV, key vendors include ITT Wedeco, Trojan Technologies (a Danaher company), and Siemens Water Technologies. The relatively new ozonation and advanced oxidation markets include major players like Ozonia and APTwater. Suez (via Degremont/Ozonia), ITT Wedeco, Mitsubishi, and Fuji have all invested heavily in ozone-based disinfection technologies. Manufacturers of peracetic acid include Solvay Chemicals (a Belgian company) and FMC Corporation (a US company).

A competitive advantage in this industry is to be aware of all existing and upcoming regulations so that solutions can allow a municipality or end user to remain in compliance at all times. Usually, the companies that can navigate the regulatory markets and help clients to understand them are the companies that attract the earliest and largest market share.

While vendors of disinfection technologies and solutions are located all throughout the US, the majority of market players are found on the West Coast. In particular, vendors are located in states such as California, which has the highest presence of disinfection companies, Oregon, and Washington. A few companies are based on the East Coast, but in no concentrated area (Ferrate Treatment Technologies is based in Florida while Hydro-Photon is based in Maine).

Certain states offer disinfection technology vendors increasingly attractive opportunities to pilot or sell their products. For example, California's constant battle with water shortage issues has caused the state to rely heavily on wastewater reuse. The wastewater in California, however, has been found to have a high level of Total Dissolved Solids (TDS), which is a common byproduct of water softeners. Santa Clarita Valley and Inland Empire, as a result, have recently introduced or enforced "Softener Bans" banning residents from putting customary water softeners in their own homes. This presents a unique selling opportunity for HydroNovation, a Santa Cruz, CA-based company, which is developing chemical-free, low power water disinfection technology based on a continuous electrodeionization process. The company's new HydroDI whole house water treatment system may provide an alternative to the traditional salt-based softeners that are commonly banned in California's residences.

4.5 Venture Activity

Global venture activity in disinfection remained relatively stable at $50.5 million in 2011 (compared to $51.3 million in 2010). In the last two years, companies providing point-of-use disinfection solutions have seen the most funding, with Quench raising a total of $43 million and WaterHealth raising $50 million (combined with its India subsidiary). While these deals certainly demonstrate impressive fundraising efforts for water treatment companies, the largest deal was actually seen in the form of an acquisition. Ecolab, a provider of cleaning, sanitizing, food safety and infection prevention products and services for industrial markets, acquired Nalco for $5.4 billion (or 34% above its market value on NYSE). Nalco, a provider of water disinfection and process improvement services, will bring industrial water treatment (particularly oil drilling and food production) to Ecolab's portfolio of services and in return, will benefit from increased access to funds for various growth investments.

The growth of alternative disinfection technologies is demonstrated by the aforementioned investments by global enterprises and the recent mergers and acquisitions (M&A) activity outlined above. Additional funding (venture capital and other) raised by companies during the 2009-2011 period is outlined in the following chart.

Company	Country	Description	Capital raise	Round
Quench	USA	Maker and distributor of water purification 'point-of-use' coolers that utilize ultraviolet light technology.	$30,000,000 $13,000,000	Growth Equity Series B
Waterleau Global Water Technology	Belgium	Provider of water treatment, processing and purification technology and services	$27,030,000	Growth Equity
WaterHealth	USA India	Provider of water purification and disinfection technology to underserved rural and peri-urban communities.	$22,100,000 $10,000,000 *India* $15,000,000 $2,660,998	Growth Equity Series D Structured Debt Growth Equity
HaloSource	USA	Developer of antimicrobial coatings and drinking water treatment products.	$10,000,000	Growth Equity
MIOX	USA	Manufacturer of water purification equipment that uses salt electroysis to generate chlorine disinfectant.	$5,000,000	Series C
AquaMost	USA	Developer of an advanced oxidation technology that uses ultraviolet radiation to activate a titanium dioxide (TiO_2)-based photoactive electrode.	$3,000,000 $1,000,000	Series B Research Grant
Claranor	France	Developers of low-energy, zero water consumption pulsed light disinfectant technology.	$3,500,000	Series C
Hydro-Photon	USA	Developer of a handheld device - Steripen - that utilizes ultraviolet light to purify water.	$2,000,000	Series A
Clarizon	UK	Developer of an electrochemical cell technology that generates ozone directly into water.	$950,000	Series A
Puralytics	USA	Developer of photochemical water purification technology.	$830,000	Seed
AquaPure Technologies	Israel	Developer of an advanced oxidation technology for water treatment with focus on MTBE treatment, metal removal and site remediation.	$720,000	Growth Equity
Wadis	Israel	Developers of water disinfection method based on pulsed power technology.	$500,000	Seed
APTwater	USA	Developer of ozone-based advanced oxidation technologies that reportedly create no disinfection byproducts.	Undisclosed	Series A
HydroNovation	USA	Developer of chemical free, low power technology to create high purity water through a continuous electrodeionization process.	Undisclosed Undisclosed	Series A Series B
Bio-UV	France	Manufacturer of ultraviolet water treatment equipment.	Undisclosed	Growth Equity
VRTX Technologies	USA	Provider of chemical-free water treatment for cooling towers and evaporative condensers.	Undisclosed	Private Equity

4.6 Company Profiles

- Purifics
- HaloSource
- MIOX

5 Water Quality Monitoring

Water Quality Monitoring enables utilities to monitor water quality through the detection of specific contaminants regulated by EPA or otherwise indicative of potential distribution network weaknesses. This market is fast-evolving, with increasing crossover to advanced water metering and other smart water technologies. Technology advancements in these sectors are slowly moving market participants towards a system of total water management, which integrates technologies to address problems faced by plant managers (e.g., water supply, water quality). Key market drivers and challenges are highlighted below:

Drivers	• Technology driver – improved technology enables detection of endocrine disruptors and other previously undetectable contaminants • Social driver – threat of deliberate surface water contamination • Market driver – aging infrastructure increases risk of mass contamination through equipment/system failure
Challenges	• Economic challenge – high capital and labor costs • Regulatory challenge – lack of continuous water quality monitoring regulations and archaic water purity standards leave little incentive to innovate

5.1 Market

We estimate the US water testing market in 2011 to be roughly $900 million across two solution segments: (i) lab testing services and related equipment, and (ii) in-line monitoring equipment (for supplying real time measurement along the pipe infrastructure). The lab testing services market reached an estimated $625 million in 2011, with specialty testing equipment reaching $160 million.[26] Rough projections place the in-line monitor equipment market at $50 million, with an additional $70 million in design and maintenance services. Global Water Intelligence estimates a historical growth rate of 3-4% percent across the sector; assuming a similar rate going

[26] *Water Technology Markets 2010* (GWI 2009); Cleantech Group Analysis

forward, the market is poised to reach $1 billion by 2016.[27] With several drivers leading to increased concern over water quality, we believe this is a conservative estimate.[28]

Utilities are not only responding to tightening regulations around the presence of endocrine disruptors in drinking water supply, but also to the threat of deliberate surface water contamination, which became a major concern after the 9/11 attacks in New York, NY. Additionally, utilities are becoming more and more proactive in their management of water plants in hopes of better managing capital expenditures. Pipe breaks, biofouling, and corrosion are all elements of aging infrastructure that can be detected through water quality monitoring equipment, especially when combined with other smart water technologies.

In this regard, the poor state of infrastructure in the US makes it a uniquely attractive market opportunity, but global opportunities do exist. For global adoption, opportunities will be defined primarily by the specific contaminants regulated in global standards, such as those set by the World Health Organization (WHO).

Factors affecting the growth of this market include the high cost of purchasing this technology and the high labor costs associated with employing qualified personnel that can handle the monitoring instruments and interpret the acquired data. The expensive undertaking is difficult for utilities to justify, especially in the absence of regulations. Market participants consistently noted real-time water quality monitoring as an area where new requirements could directly stimulate innovation and purchasing.

5.2 Policy and Regulation

Currently, in the US, there are no regulations around continuous water quality monitoring throughout a plant. The closest piece of legislation has been the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Bioterrorism Act of 2002), which requires

[27] *Water Technology Markets 2010* (GWI 2009); Cleantech Group Analysis

[28] We adopted a conservative estimate given a potential lag on traditional lab test services. Newer testing solutions are increasingly being sold as self-contained systems (featuring equipment and software) that allow plant operators to detect and identify contaminants without consulting outside specialists. One industry expert estimates that if the newer solutions continue to be released under this business model, the service market will eventually account for only 10-20% of equipment.

drinking water systems of a certain size to conduct vulnerability assessments and develop or update emergency response plans that address potential terrorist threats. Beyond this, however, utilities lack a tangible incentive to invest in and implement water quality monitoring technologies. Without the threat of consequences – monetary or otherwise – utilities are not being forced to recognize the vulnerability of their water systems and are thus not prioritizing water quality management above other measures.

Rather, regulations such as the CWA and SDWA govern quality testing of water only once it is treated to potable standards. Existing methods of testing water quality have been around for decades, and as such have become entrenched within the drinking water sector. While improved testing technologies enable the detection of previously undetectable contaminants, any changes are likely to require an upgrade of existing treatment systems and be costly for water treatment plants. For example, the WHO set a widely accepted guideline that drinking water should not contain more than 0.01mg/L of bromate – a level set so low that, until recently, there was no equipment available to measure it. When an effective measurement of bromate was introduced by the emirate of Fujairah's water utility in 2005, it discovered that bromate levels exceeded the WHO maximum tenfold. This prompted water agencies across the Gulf region to reevaluate their disinfection methods.

The widespread use and acceptance of existing water quality tests provides minimal incentive for utilities to adopt technology that more accurately detects contaminants to levels outside of regulation. Thus, while university laboratories continue to develop innovative contaminant analysis techniques, few of these are likely to be adopted by the water industry until more stringent water testing measures are implemented.

Additionally, the system of dual regulation (federal and state) creates a problem for innovators concerned with the development of contaminant testing solutions, as all technologies must be approved by both EPA and individual states before utilities can adopt them. The inherent difficulty in obtaining such approvals places a significant cost and time burden on innovators, consequently stifling innovation and investment in this area. For instance, one vendor of water quality monitoring technology quoted the required allocation of $350,000 worth of staff hours to complete certification as the reason for refocusing efforts on the process control markets within the chemicals and pharmaceuticals industries, where there are more predictable returns on investment. Other vendors have noted the approval timeline, which can range anywhere from 6 months to 5 years, as overly burdensome in marketing solutions to potential clients.

5.3 Technologies

5.3.1 Products

Despite the lack of clear regulatory drivers, the water quality monitoring market has seen some innovation primarily focused on water security-related monitoring. Innovation includes the development and enhancement of online single-and multi-parameter sensors, optical sensors, and various bio-sentinel type sensor solutions, which, compared to traditional sensors, provide improved information. These technologies have been briefly outlined below.

Single- and multi-parameter sensors: These are electro-mechanical measurement devices (e.g., membrane, electrode, or microchip) that convert physical and chemical characteristics of water into "signals" or measured values of parameters in real-time that can be further processed and analyzed. Traditional single parameter sensors measure one water quality parameter at a time, while the multi-parameter instruments can measure more than one parameter at a time. As an alternative, companies like Hach and S-can have introduced instrument panels that include up to 7 different sensors in one integrated system.

Optical sensors: These technologies provide interpretative (versus direct) measurements of water quality changes by monitoring variance in light refractive index, absorption, fluorescence, and/or transmission at selected light wavelengths through the sample water volume. The measured value in some cases is also quantified by applying specific algorithms and expressed as equivalent measured value(s) of a specific water quality parameter such as Total Organic Carbon, Turbidity, Nitrates, etc. Another commercially available optical sensor is capable of detecting biological contamination using multiple angle light scattering properties of the organisms (e.g., JMAR). These optical sensors are gaining some deployment momentum as they require minimal operational maintenance and are comparable in price to the more traditional sensors. Other vendors in this arena include S-can, Realtech, Hach, ZAPS technologies, and Optiqua.

Bio-sentinel sensors: These are biological instruments that are based on monitoring the behavior changes of a "sentinel organism." For example, algae- or bacteria-based sensors are based on fluorescence. In the case of an algae-based sensor, as algae are exposed to toxins, the photosynthetic activity of the algae is suppressed, and the sensor is designed to detect these changes and report toxic events. Other existing organism-based water toxicity sensors include fish, bi-valves, daphnia, and genetically engineered frogs. However, operation of these bio-sentinels requires a somewhat high level of technical expertise. Consequently, this market has not seen the levels of market penetration or venture funding associated with other water technologies (see Section 5.5).

Significant potential for growth in this sector lies at the nexus of water quality testing and smart water. Where innovators of real time contaminant detection apparatus are able to relay the information from remote sensors to a central network control center, there is a great opportunity to create a cohesive water quality management system. This would enable utilities to monitor water quality in real time and respond to contamination issues with immediacy. As such, there are many parallels that can be drawn between the opportunities within the water quality monitoring market and the system metering market. Thus, it is likely that many smart water innovators will either move into the water quality monitoring field or, more likely, subsume water quality monitoring into their systems to establish total water management systems.

5.3.2 Services

Laboratory testing and analysis represents the service sector of this market. Nearly half of the testing is conducted in-house, in onsite laboratories that are a part of water and wastewater treatment plants or industrial plants. The other half of testing is done by commercial laboratories, most of which tend to run very small operations due to their specific geographic focus. While there are a few major lab groups in the world, they account for less than a quarter of all water testing.[29] The laboratory water testing market within the US was estimated at $600 million in 2008, accounting for just one third of the overall laboratory testing market.

5.4 Vendor landscape

Providers of water quality monitoring solutions are distributed throughout the US, with Colorado serving as home to two of the largest manufacturers of in-line monitoring equipment, Hach Company and Siemens, while YSI (acquired by ITT Corporation and now part of Xylem) is based in Ohio. Other large manufacturers of testing equipment include Agilent (a Hewlett Packard spin-off), Thermo Scientific (who acquired Dionex, another major US manufacturer of high-end lab equipment, in May 2011), and Waters. Smaller players in this market include Fluid Imaging Technologies and ZAPS Technologies.

5.5 Venture Activity

Despite the stifling effect of the entrenched drinking water purity standards, companies in the water quality monitoring space have seen a healthy number of investment deals since 2009. The size of each deal, however, is generally smaller than other sectors within the water industry. Due to this and the fact that many companies choose not to disclose transaction values, total funding of $1.2 million in 2011 was down from $5.5 million in 2010 despite a higher number of deals. The largest deals have gone to companies that offer real-time monitoring and testing solutions, indicating market appetite for established technologies that offer utilities improved (i.e., cost- and time-efficient) ways of testing water quality. The lack of funding in innovative technologies that monitor contaminants on an ongoing basis shows the novelty of these solutions, and it may take time for the market to understand and appreciate their added value. It is also interesting to note that with the exception of two deals for undisclosed amounts, all companies that raised money are located outside of the US. Rather, the US water quality monitoring market has seen a significant amount of movement through M&A activity and spin-offs, as described above in Section 5.4.

[29] *Water Technology Markets 2010* (GWI 2009).

While funding is extremely important to startups introducing new technologies, it is not the only key to success. JMAR LLC, a San Diego, CA-based provider of laser-based solutions that allow for microbiological detection of organisms in water, announced in early 2012 that the company would lay off 80% of its workforce and cease manufacturing, selling, and upgrading of its product on January 31, 2012. Despite attracting nearly $2.5 million of funding for two straight years and never experiencing difficulties with its equipment, the company went through long and extensive customer trials, which were coupled with a slow sales cycle. Rather than selling a minimum of 100 units per year, which would have allowed the company to break-even on a cash-flow basis, the company saw fewer than 10 units sold in 2011. JMAR's inability to survive in today's environment makes real the risk of innovative water quality monitoring companies failing as a result of a lack of funding or market appreciation of the value these technologies can provide.

The following chart outlines venture capital investments in the Water Quality Monitoring sector since 2009.

Company	Country	Description	Capital raise	Round
Neosens	France	Developer of continuous & real-time liquid quality monitoring & control sensors.	$5,400,000	Series B
Checklight	Israel	Developer of real-time water quality testing and monitoring kits and products.	$1,000,000 $2,000,000 $500,000	Growth Equity Growth Equity Minority Invstmnt
Intellitect Water	UK	Developer of water quality sensors and instruments.	$3,300,000	Follow-on
Aqualabo	France	A provider of instruments and probes for water quality monitoring, checking and analysis.	$2,800,000	Growth Equity
Sorbisense	Denmark	Developer of water quality monitoring technology for a variety of sources including drains, groundwater, drinking water, and industrial wastewater.	$1,200,000 $461,000	Growth Equity Growth Equity
Shaw Water Engineering	UK	Developer of technology to detect the presence of harmul parasites in fresh water supplies.	$1,190,000	Seed
TACount	Israel	Developer of a technology that allows for the detection of microorganisims in fluids.	$600,000 $600,000	Series A Seed
Sens-Innov	UK	Developer of sensors for water pollution.	$640,000	Seed
Zaps Technology	Spain	Producer of on-line, real-time, green water composition monitoring equipment.	$569,596	Series A
EnPrint	UK	Developer of applied DNA fingerprinting technology to deliver an accurate assesment of water quality.	$248,400	Seed
BiAqua	Netherlands	Developer of bio-based contamination detection in water treatment.	Undisclosed	Series A
SecureWaters	USA	Manufacturer of a front-end electronic monitor/alarm system that offers continuous protection of drinking water sources by measuring changes in algae characteristics.	Undisclosed	Seed
American Micro Dectection Systems	USA	Developer of a system that detects toxic metals in water networks.	Undisclosed	Minority Investment

5.6 Company Profiles

We profile four the following three companies due to their innovative technology.

- SecureWaters
- OndaVia
- ENDETEC

6 Smart Water Metering

Water meters collect and register information on the volume of water used over a period of time at a particular location, allowing utilities to accurately monitor water usage and bill end users. Smart water meters go one step further, with the ability to help utilities identify and mitigate instances of inaccurate water metering, improperly sized and typed water meters, billing system errors, and theft of service. The sector has gained special attention in recent years as utilities face decreased levels of federal funding, and are therefore more concerned with capturing all possible revenue from the distribution of treated water. Key market drivers and challenges are highlighted below:

Drivers	• Economic driver – utilities want to reduce/eliminate non-revenue water (water lost due to unmetered users, faulty meters, or undetected leaks) • Technology driver – improved efficiency through real-time detection of system leakage • Technology driver – proven successful implementations of transferable technology within the energy and technology markets • Social driver – data enables better understanding of water usage and therefore can promote water conservation
Challenges	• Economic challenge – high capital costs and labor costs associated with installation and maintenance of smart water meters • Social challenge – reluctance of end users to invest where tariffs are set below the cost of services

6.1 Market

While dwarfed by the rollout of electric smart meters, smart water meters are starting to gain traction in the US and the market is poised for steady growth. We estimate a current market size of $640M growing at 9.3% CAGR to approach a $1B by 2016. [30] Related equipment (including

[30] *Water Market USA 2011* (GWI 2010), *The World Market for Water Meters – 2011* (IMS Research); Cleantech Group Analysis

meters, communication modules, and networking equipment for deployments) are estimated at $310 million in 2011, with meter planning and deployment services—including program management, network planning and installation, and systems integration— an additional 0.5-1.0x on equipment sales (or $160-$310 million).

Utilities are becoming more inclined to invest in smart water meters and incorporate them in future fixed network infrastructure, particularly as the price of two-way meters gradually decreases and becomes comparable to one-way meters. This upgrade will provide utilities and end users with more data on water consumption patterns, and therefore may stimulate more effective water conservation programs. These types of programs have received an increasing amount of attention especially as the growing world population makes water scarcity a real concern. Additionally, the water industry is starting to develop analogous needs to the electricity industry, where rising energy prices and the desire of both consumers and utilities to better manage electricity use has been the driving force behind deploying more advanced metering infrastructure in the electric grid.

When examining the rollout of smart electricity meters and the level of resistance electric utilities faced, it can be seen that public acceptance of smart water meters has the potential to pose a barrier to growth. Some public misconceptions regarding electricity meters are not applicable to smart water meters, such as increased exposure to radio and electromagnetic waves, while others are more relevant. For example, water utility customers have voiced concerns over compromised personal privacy and potential rate increases. Water utilities will need to address and debunk these myths in order to successfully rollout smart water meters.

The North American market for smart water meters is attractive due to the absence of a regulated water meter replacement rate (as seen in parts of Europe) and high manual labor costs (which further justify the move to automated meter reading). Currently the largest market for advanced metering, North America accounted for over 65% of global advanced water meter shipments in 2010.[31] As the penetration of advanced water metering increases, global

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[31] *The World Market for Water Meters – 2011* (IMS Research)

opportunities do exist, but it will take a number of years for the international AMR market to reach that of North America. The global AMR market was estimated at about 5.5 million global shipments in 2010, totaling over $500 million in revenue, and is expected to increase to nearly 10 million by 2016.[32]

6.2 Policy and Regulation

There are currently no regulations around traditional water metering in the US, as the technology is mainly concerned with data gathering and analysis—actions that are outside of water quality. Though many municipalities are challenged by EPA to conduct infrastructure upgrades to maintain system performance and ensure system enhancements in order to continue to maximize utility and city services.

6.3 Technologies

6.3.1 Products

Water meters are standalone devices composed of metal and/or plastic, and typically range in size from 5/8" to 2" in diameter for residential and commercial customers.[33] Historically, meters were read via the "eyeball" approach, in which a meter reader would physically go to the meter, estimate usage based on what is displayed on the meter's register, and record this information on a paper form that is later transferred to a utility's billing system. This labor-intensive and relatively inaccurate process would occur at least every quarter, but sometimes every month. Since then, the method has evolved to "walk-by" meter readings, which allow a meter reader to use a handheld computer device to read and record water usage information. Gradually, however, utilities are moving to smart water meters, which can communicate directly with water utilities and allow for meter readings on demand. Smart water meters consist of automated meter reading (AMR) and advanced metering infrastructure (AMI).

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[32] *The World Market for Water Meters – 2011* (IMS Research)
[33] https://media.blackhat.com/bh-us-11/McNabb/BH_US_11_McNabb_Wireless_Water_Meter_WP.pdf

Automated Meter Reading (AMR): AMR meters integrate communication units to transmit data in at least one direction. Most AMR meters are radio frequency (RF) devices that are read by drive-by or handheld receivers. These meters transmit data in near real-time usage, with up to tens of thousands of data transmissions possible in one day. This frequent broadcasting of data ensures utility workers in close proximity to the meters can collect the information at virtually any time. The automated process helps to reduce a utility's operational and maintenance costs and to increase billable water usage. These meters have only slowly (albeit steadily) been replacing legacy meters that require access to private homes for visual inspection and meter reading, as funding is a significant challenge for utilities. It is estimated that approximately 25% of the 90-92 million water meters currently in use in the US have been outfitted with AMR functionality.[34]

Advanced Metering Infrastructure (AMI): The second generation of AMR meters, known as AMI, allow for bi-directional communication to and from the meter primarily over fixed wireless networks. These meters typically transmit stored readings once a day, but have the capability to send readings on demand when prompted by a utility. The investment case for AMI has not yet been compelling for most water utilities, despite the promise of enabling utilities and consumers to better understand water usage and the operational benefit of enabling utilities to more accurately identify leaks and other operational problems. We estimate that only 10% of AMR units deployed by water utilities would be classified as AMI. In comparison, AMI deployments have seen fast adoption amongst electric utilities that received project funding through the American Recovery and Reinvestment Act of 2009. By 2010, electric utilities had deployed approximately 20 million AMI units.[35] The one benefit of this delayed deployment is that AMI technology continues to mature through its deployment by electric and gas utilities. In the electricity space, mobile AMR systems cannot support daily collection of time-of-use data or remote meter reprogramming, causing more and more utilities to shift to AMI meters. Fortunately, many electric AMI systems are designed to support water utility metering. It is

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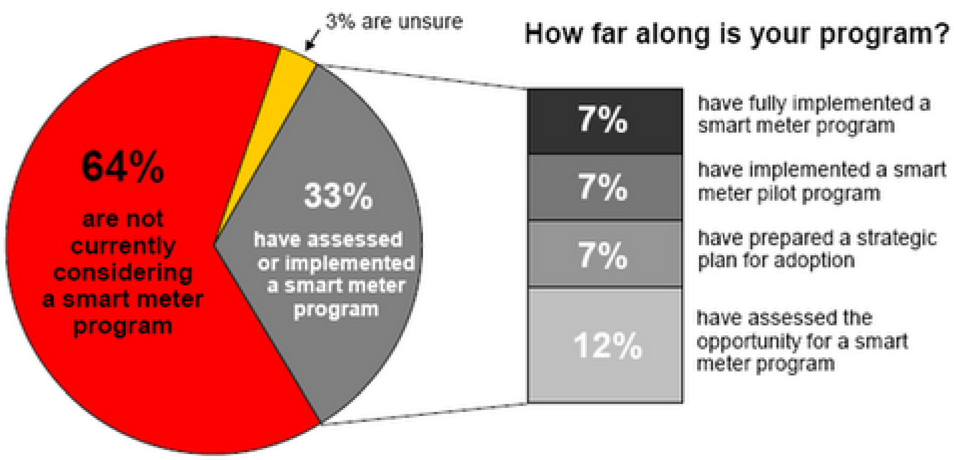
[34] Dr. Howard Scott, Managing Director of Cognyst Consulting
[35] *2010 U.S. Smart Grid Vendor Ecosystem Report* (Cleantech Group)

expected that reliability of AMI meters will increase over time and costs will decline, enabling water utilities to reap these benefits in future implementations.

The adoption estimates outlined above are in line with a recent water utility study published by Oracle. The study found that only 7% of water utilities have implemented a smart meter program with an additional 7% in pilot phases, while 64% had not yet even considered a smart water meter program.



Larger water utilities (100 employees or more) are more than twice as likely as smaller water utilities (less than 20 employees) to consider or implement smart meter technologies – 59% to 26%, respectively

Source: Oracle, Environmental Leader

6.3.2 Services

Many of the companies that offer smart water metering solutions will take care of the installation and maintenance services, eliminating the need to involve EPC or design engineering firms. To collect data, city workers may be employed for remote meter readings from their vehicle. Once the data is collected, utilities must employ skilled engineers to monitor and analyze the data. These engineers are responsible for identifying accounts that appear to have either abnormally high or low billed usage or accounts that generate conditional alarms caused by periodic spikes in daily usage.

Many utilities may choose to implement a meter data management (MDM) program to assist their engineers analyze and use meter data. MDM systems perform long term storage and management of the vast quantities of data that are captured by AMR and AMI devices. While many meter providers offer MDM solutions, some equipment providers will refer clients to outside companies. Major MDM system providers in the US include Aclara, eMeter, and Ecologic Analytics. Itron and Oracle are two MDM system providers that also sell water meters.

6.4 Vendor landscape

Within the US water metering market, we have seen dominance by a small number of large, established vendors. Badger Meter, Neptune, and Master Meter account for the majority of automated meter deployments. Itron, Elster, and Sensus are thought to be the global leaders with 14% market share each.[36]

Also, companies like Silver Spring Networks and Trilliant, which do not manufacture meters but rather focus on communication units, are partnering with vendors that integrate communication units into water meter hardware (e.g., Itron, GE, and Landis+Gyr). These companies have primarily targeted electric utilities, but are beginning to penetrate the water market due to the relative ease of transferring technology between the two sectors.

Large IT players including Cisco, IBM, and Oracle are also increasingly interested in the water business and the opportunity to exploit the convergence between IT and water—specifically where data aggregation, management, and control are concerned. Yet some water industry veterans argue that there is a limit to the role of IT in water, where environments are harsh and regulation is extremely thick.

There is no one region of the US that boasts a concentrated presence of water meter vendors. In fact, both the West Coast and East Coast have an equal showing of meaningful technology providers, with Itron and On-Ramp Wireless in Washington and California, respectively, and Bentley, Sensus, and Elster AMCO in Pennsylvania, North Carolina, and Florida, respectively. The

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[36] *Water Technology Markets 2010* (GWI 2009).

South also houses technology vendors, with Capstone Metering and Master Meter both located in Texas.

6.5 Venture activity

Globally, smart water has seen a rapid increase in the amount of VC funding going to the sector – 2011's total $27.7 million was 59% higher than 2010's total $17.4 million. Specifically within the water metering sector the majority of investment activity has been aimed at providing seed funding for new entrants (with the exception of i2O Water). This is consistent with expectations, as many of the large providers of smart water metering solutions are well-established smart grid companies that are not seeking funding, but rather focus on partnerships or M&A transactions. The fact that so many new entrants have been able to secure financing is further indication that the smart water industry is on the verge of taking off. Venture funding for smart water metering companies, starting from 2009, is shown in the table below. It should be noted that the venture capital funding catalogued below only covers investment in companies that operate entirely in the water sector.

Company	Country	Description	Capital raise	Round
i20 Water	UK	Developer of a smart metering and pressure control system ensuring the average zone pressure in the pipes is kept to the minimum required, leading to reduced leaks and bursts.	$15,700,000 $6,350,000	Series C Series B
On-Ramp Wireless	USA	Developer of wireless communication systems for the water, smart grid and other industries that allow device communication in hard to reach environments.	$11,500,000 $4,500,000	Series B Series A
Ikor Metering	Spain	Provider of water and gas metering products.	$1,900,000	Seed
Aquacue	USA	Provider of water meter monitor and Internet-based water use efficiency solutions to monitor and compare water use.	$1,000,000	Series A
WaterSmart Software	USA	Provider of software and services to utilities aimed at providing customer access to water use information and water saving solutions.	$900,000	Seed
Hydrospin	Israel	Developer of inside pipe generator that supplies electricity for water monitoring and control systems.	$500,000	Seed
TaKaDu	Israel	Provider of a web based platform that monitors water distribution networks.	Undisclosed Undisclosed	Series B Series A

6.6 Company Profiles

We have selected the following four companies for profiling on the basis of their innovative technologies and recent venture appetite for their product:

- On-Ramp Wireless
- Capstone Metering
- TaKaDu
- Aquarius Spectrum

7 Infrastructure Assessment

In its 2009 Report Card of America's Infrastructure, the American Society of Civil Engineers (ASCE) awarded the US network of drinking water and wastewater systems a D-.[37] Leaking pipes in the US result in 7 billion gallons of clean drinking water lost each day, equating to 18% of all treated water. This can be monetized as a real loss of approximately $7 billion per year.[38] To address this problem, utilities may choose to implement smart water meters or condition assessment solutions, or a combination of the two. Condition assessment technology checks the integrity of buried drinking water mains and allows a utility to identify which pipes are in worst condition and should therefore be replaced first. The vast room for improvement of water utility distribution systems signifies vast market growth opportunity for condition assessment vendors. Key market drivers and challenges are highlighted below:

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[37] *2009 Report Card on Infrastructure* (American Society of Civil Engineers). http://www.infrastructurereportcard.org/fact-sheet/drinking-water; http://www.infrastructurereportcard.org/fact-sheet/wastewater

[38] *Water Technology Markets 2010* (GWI 2009).

Drivers	• Economic driver – allows utilities to be more cost-efficient with infrastructure repairs • Economic driver – reduces loss of non-revenue water • Economic driver – water captured through pipe repairs is more economic than finding new water source through dam, reservoir, etc. • Social driver – water scarcity concerns
Challenges	• Technology challenge – utilities are hesitant to deploy any technologies that may potentially disrupt water distribution services or quality

7.1 Market

The overall infrastructure market (including pipes, pumps, and valves) is very large, reaching $12.4 billion in 2011.[39] Moreover, site work and rehab services introduce another $13.4 billion of expenditures on the market. Given this vast backdrop of infrastructure spend and related services, it is no surprise we are seeing innovation solutions to address it, including our focus in this section: infrastructure assessment.

With extensive real loss from underperforming water infrastructure, there exists significant market potential for those who can efficiently identify problems. Based on projected overall infrastructure spend and interviews with key condition assessment vendors, we estimate the US water infrastructure assessment market to be roughly $260 million in 2011, across two solution segments: (i) condition assessment tools and other related equipment, and (ii) engineering services (to conduct the assessment). The equipment market is estimated at nearly $50 million, with utilities often leasing equipment from vendors. Contracted services account for the remaining $210 million, in which utilities retain engineering consulting firms or technology vendors' engineers to perform assessments.

In addition to pure water loss, public health concerns are increasingly becoming a key concern, as leaky pipes pose the threat of introducing external contaminants while transporting treated

[39] *Water Market USA 2011* (GWI, 2010)

water. In the event a water-borne illness is introduced, it could result in increased medical expenditures for households or decreased labor productivity given necessary use of sick days. Utilities would inevitably be blamed for neglecting water infrastructure, resulting in negative press (which is often cited as a utility's worst fear). Also, promoting the growth of this market is the fact that by identifying and fixing leaks within the distribution network, plants can reduce or eliminate the loss of unaccounted for water that has undergone expensive treatment processes. In addition, they can better assess asset values and understand remaining useful life of these assets, allowing for more effective management of their budget. These typically cash-strapped utilities, when faced with the task of replacing water mains on a periodic basis, are predicted to start turning more readily to condition assessment solutions in order to identify the most effective repairs. According to ITT's nationwide "Value of Water" Survey, there are numerous instances in which pipes meant to last for 50-75 years have been in operation for 100 years or more.[40]

A barrier, however, is utilities' lack of education on condition assessment technologies. Despite the fact that condition assessment technologies can help alleviate the consequences associated with failure of a given pipe, utilities are yet to set these technologies as a funding priority for fear of disrupted water supply for end users. Although some technologies do require pipes to be out of service, emptied and cleaned, innovators have developed a number of non-disruptive solutions that do not affect water distribution. Some utilities have even voiced concerns regarding potential contamination of treated water supplies from introducing inspection tools into operational mains. Additionally, it is nearly impossible for utilities to make true cost/benefit decisions regarding adoption of this technology due to the difficulty in quantifying the immediate value of information gathered through condition assessments.

In the England and Wales region, water loss is a serious concern, and Ofwat, the water regulator, has made significant efforts to collect statistics around water leaks. Using this data, Ofwat

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[40] ITT Value of Water Survey, 2011.
http://www.itt.com/valueofwater/media/ITT%20Value%20of%20Water%20Survey.pdf

managed to curb water loss nearly 30% from 1995 – 2005.[41] Outside of the US, Australia leads the globe in matching England and Wales' data tracking efforts of water leakages, therefore positioning itself as an attractive and open market for condition assessment technologies.

7.2 Policy and Regulation

Federal drinking water standards motivate drinking water plants to consider regular upgrades to infrastructure. Wastewater plants, however, are subject to regulation in the form of EPA consent decrees, which, in one primary interview, were referred to as "administrative nightmares". Consent decrees are a regulatory tool used by EPA to take legal actions against large polluters. With an estimated 900 billion gallons of untreated wastewater discharged every year as a result of leaky pipes and inadequate capacity[42], it is no surprise that nearly 28% of U.S public water systems had at least one significant EPA violation reported in 2009.[43] Utilities have recently become more proactive in the maintenance of their systems in order to decrease the mental stress and financial liability of consent decrees.

If utilities choose to undergo water mains rehabilitation, there are certain standards that must be met. For example, NSF/ANSI Standard 61 establishes "minimum health effects requirements for materials, components, products, or systems that contact drinking water, drinking water treatment chemicals, or both." The standard covers pipes and other mechanical devices used in water distribution, resulting in utilities selecting vendors that offer products specially designed to meet these various standards.

[41] "Turning losses into gains". *Global Water Intelligence*, December 2006. http://www.globalwaterintel.com/archive/7/12/market-insight/turning-losses-into-gains.html
[42] *Failure to Act: The Economic Impact of Current Investment Trends in Water & Wastewater Treatment Infrastructure* (American Society of Civil Engineers). http://www.asce.org/uploadedFiles/Infrastructure/Failure_to_Act/ASCE%20WATER%20REPORT%20FINAL.pdf
[43] http://www.epa.gov/compliance/resources/reports/accomplishments/sdwa/sdwacom2009.pdf

7.3 Technologies

7.3.1 Products

Condition assessment technologies can be indirect or direct. Indirect methods do not require access to water mains and largely include the analysis of historical data (e.g., failures, water audits, and flow tests) rather than the use of physical equipment. In contrast, direct methods engage and collect data from internal and/or external surfaces of the water distribution network, producing a higher level of detail, timeliness, and confidence in condition assessment results. Popular direct solutions include cameras, closed circuit television (CCTV) and acoustic leak detection technologies.

Since water pipeline systems are comprised of different types of pipe (e.g., concrete, metallic) buried in variable surroundings, different solutions may target different markets. Solutions that can be easily inserted and retrieved from a pipeline, and can assess the quality and condition of various pipes without interrupting water distribution services, will enjoy the most success. The conservative nature of utilities, who understandably cite disruption of water delivery as one of their main concerns, view these as significant competitive advantages for any condition assessment technology provider.

Closed circuit television (CCTV): CCTV, a commonly used tool for inspecting pipes, involves a video camera that moves through a distribution network and records the condition of interior pipe surfaces. A drawback to this technology is that only the pipe surface above the waterline is captured on record. Additionally, this can be an expensive solution due to the necessity of cleaning pipes before inserting the video camera. Costs increase with the depth of the distribution network due to longer set-up times required and longer cables needed to reach pipes from the surface. Sonar images are increasingly being used in conjunction with CCTV, as they allow users to inspect pipes below the water line, providing a complete picture of the piping system.

Cameras: Cameras are another well-established and common method of condition assessment. Cameras can be mounted on trucks, and are often equipped with long-range zoom lens and powerful halogen spotlights. Cameras are now also available with side-scanning features, increased zoom inspection, and image stabilization capabilities, making them an attractive option. Additionally, as they do not require pipes to be pre-cleaned, they are a lower cost alternative to CCTV.

Acoustic: Acoustic technologies detect signals emitted due to pipe defects. While acoustic technologies can vary based on inspection purposes, some of the more popular technologies include sonar or ultrasonic. These technologies gauge the velocity of high frequency sound waves within a pipe, and any signal-specific changes in transmission or propagation velocity, to determine the presence of any defects.

Ground Penetrating Radar (GPR): GPR emits radio waves into the ground and measures the strength and delay of resulting echoes (or refraction waves). This technology is used more often for leak identification, as radio waves are slowed down by saturated soil, than for condition assessment.

7.3.2 Services

Often, technology vendors will directly interact with utilities to pilot and sell their solutions, and then continue in the role of an engineering firm to implement and conduct the condition assessment. For example, Pure Technologies, a Calgary, Canada-based provider of technologies for water pipe inspection, monitoring and management of water infrastructure, typically offers utilities a combination of technology and engineering services. The company works side-by-side with a client to monitor pipes and identify leaks in what could be a multi-year commitment. The company also offers one-off services, meaning utilities can choose to retain Pure Technologies solely for its leak detection technology or for its services.

In instances when only technology is bought, utilities may choose to engage a separate consulting or engineering firm, such as Black & Veatch, to perform the condition assessment. Black & Veatch has completed a number of important condition assessment studies on strategic large diameter water mains both in the US as well as overseas.

7.4 Vendor landscape

Key vendors of condition assessment solutions include Fluid Conservation Systems (a Halma company), Echologics (a Mueller company), In-Pipe Technology, RedZone Robotics, and Pure Technologies (who acquired Pressure Pipe Inspection Company in 2010 and Electromechanical Technologies in 2011). Many technology vendors target specific types of pipes and ultimately strive to be a leader in that sector. For example, Pure Technologies focuses its condition assessment technology on large diameter pipelines. The company plans to move into condition assessment solutions for other pipe types, largely through acquisitions.

While infrastructure needs generally tend to parallel population increases and greater economic activity, as seen in certain parts of the West Coast and Southeast regions, solutions vendors are not as strategically located. Some of the largest vendors are based in the Northeast region and in close proximity to Ontario, Canada.

7.5 Venture activity

While VC funding for infrastructure assessment companies grew to $27.7 million in 2011, from $5.1 million in 2010, this is not indicative of a new trend we expect to see in the sector. RedZone Robotics, a sewer pipeline inspection company, saw a $25 million financing round that accounted for the large majority of 2011 VC activity. A trend that is worth noting, however, is that much of the large financing activity in the Infrastructure Management sector has gone to service providers that work with utilities to optimize water management operations. When taking a look specifically at condition assessment equipment providers, investment activity is more in line with that of Water Metering, a closely related sector.

Due to the fragmented nature of this market (as solutions are commonly tailored to specific types of pipes and distribution systems), M&A activity is particularly strong. As previously noted, Canadian-based Pure Technologies acquired Emerald Technology Ventures-backed Pressure Pipe Inspection Co. (PPIC) to broaden its international exposure. PPIC currently has customers not only in North America but also in South America, the Philippines and Hong Kong. More recently, Pure Technologies acquired Electromechanic Technologies to move into the metallic pipe assessment space.

Company	Country	Description	Capital raise	Round
Hyflux	Singapore	Provider of integrated water management and environmental solutions.	$116,000,000	Project Finance
RedZone Robotics	USA	Provider of sewer pipeline inspection products and services.	$8,500,000 $25,000,000 Undisclosed	Series D Series C Structured Debt
i2O Water	UK	Water technology vendor addressing water leakage and advanced pressure management for utilities.	$15,700,000 $6,350,000	Series C Series B
Pratibha Industries	India	Provider of integrated water transmission & distribution projects, water treatment plants, elevated and underground reservoirs.	$11,250,000	Private Equity
SMS Paryavaran	India	Provider of water transmission, treatment, storage and distribution solutions.	$8,700,000	Growth Equity
Insituform Technologies	USA	Provider of technologies and services for rehabilitating sewer, water, energy and mining piping systems and the corrosion protection of industrial pipelines.	$4,000,000 $2,500,000	Series B Series A
Hydrelis	France	Developer of leak detection systems and water management systems.	$4,632,977	Series A
Syrinix	UK	Developer of leak detection systems on trunk main water distribution networks, allowing a repair to be made before the pipe fails catastrophically.	$900,000	Seed
Curapipe Systems	Israel	Developer of a leak curing solution for buried pipelines, primarily within urban water distribution networks that constantly leak.	$725,422	Series A
Aquarius Spectrum	Israel	Developer of online water leak detection systems for municipalities.	$280,000 $500,000	Seed Seed
SPC Tech	Israel	Developer of smart pressure control system to prevent leaks in water systems.	$500,000	Seed
Echologics	Canada	Developer of acoustic technologies to detect and locate leaks in fluid delivery pipeline.	$500,000	Seed
Pressure Pipe Inspection Company (PPIC)	Canada	Developer of patented technologies to evaluatewater infrastructure to reduce water losses, avoid catastrophic pipeline failures, and meet regulations.	Undisclosed	Series A
TaKaDu	Israel	Provider of a web-based platform that monitors water distribution networks, enabling utilities to detect leaks and other inefficiencies.	Undisclosed Undisclosed	Series A Series B

7.6 Company profiles

- Echologics

- Pure Technologies
- RedZone Robotics

8 Water Reuse

Wastewater is currently a $44 billion market in the US.[44] General municipal wastewater treatment methods, which include a combination of physical, chemical, and biological methods, have remained relatively the same throughout the years. Treatment typically involves 3 levels: primary, secondary, and tertiary.

Primary treatment is meant to produce an effluent suitable for biological treatment. This step often consists of temporarily holding sewage in a dormant basin to allow heavy solids to settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid is discharged or subjected to secondary treatment. During the *secondary treatment* phase, the wastewater is treated through biological oxidation to remove dissolved and suspended biological matters. This step may require a separation process to remove microorganisms from the treated water prior to discharge or tertiary treatment. *Tertiary treatment* uses additional physical, chemical or biological means to further improve the effluent quality. This step typically uses some form of filtration.

Innovation in this sector is largely defined by the emergence of reused water, which refers to reclaimed water that is collected, treated, and used without being released back into the natural water cycle. Water reuse has emerged as an attractive solution to the looming water crisis; as water consumption rates increase around the world, so does the availability of wastewater as a resource. Municipalities often cite stringent regulatory concerns, economic factors, and lack of potable water supplies as the main drivers of the reuse market.

Industrial wastewater treatment, on the other hand, has seen more advancement as effluent quality limitations have become more stringent. As a result, demand for products such as advanced membrane systems, disinfection equipment, and specialty chemicals has increased. As

[44] See Section 2.1 – The US Water Market

more and more companies find themselves investing higher dollars in additional treatment requirements to satisfy existing discharge quality limits, the benefits of reusing this highly treated water are becoming more and more apparent. Other factors promoting the concept of water reuse include the rising price of fresh water and increasingly limited access to water resources, which is thwarting growth plans. Industrial reuse is explored in more detail in the “Water Reuse” section below.

While the concept of water reuse has been around for decades, it has most typically served only the irrigation and industrial markets. A breakdown of existing applications of reused water include agricultural and landscape irrigation, industrial use (e.g., boiler feed water, facility cooling, process water), ground water storage and recovery and salt intrusion barriers in coastal communities. Very little reused water is currently leveraged for either direct or indirect potable use (high quality water), despite these being areas that represent big market opportunities. Key market drivers and challenges are highlighted below:

Drivers	• Environmental driver – provides sustainable and weather-independent water provision • Economic driver – increasing cost advantages over desalination and other supply alternatives (e.g., new dams, new reservoirs, new “purple pipe” distribution systems) • Regulatory driver – government policies (e.g., California)
Challenges	• Social challenge – negative public perception causes delays, design complications and cost overruns • Economic challenge – standalone unit economics for reuse projects not always compelling • Technology challenge – reuse projects tend to be unique based on various project-specific requirements (e.g., treatment of specific inflow contaminants, final water quality requirements, peak flow requirements, cost constraints, regulatory standards)

8.1 Market

Given the significant overlap of reuse technologies with wastewater technologies and treatment processes, it is difficult to cleanly segregate and size the water reuse market. Based on data of existing reuse projects, their combined capacities, and projected growth rates in the usage of reused water, the North American market is estimate to be $1 billion in 2011.[45] This market is projected to grow at a rapid 10.4% per year to top $1.6 billion by 2016,[46] as restrictions on potable reuse are relaxed and public perception around the use of reused water continues to evolve. Approximately $450 million of the current spend relates the equipment; the remaining $550 million owing to related services.

Several other factors will contribute to the growth of this market. For example, the economics of reuse plants are financially attractive. While improvements in membrane technologies have increased the cost-efficiency of desalination, reuse is still largely considered to be the cheaper alternative. It also has the added benefit of presenting a new revenue stream for typically financially-constrained wastewater plants. Additionally, implementing reuse systems in existing wastewater treatment plants eliminates the need to raise financing or identify land for new reservoirs or distribution systems for cities faced with urbanization. Urbanization poses a new challenge of developing water resources to meet a city's needs in the face of insufficient space for reservoirs or pipelines to transport water to new suburbs. Finally, reuse has the potential to enhance landscaping associated with improved river quality, as wastewater is no longer being discharged at the same rate.

There are also many barriers to the growth of the reuse industry. Public acceptance has been one of the largest impediments to market growth, as the concept of water reuse is still commonly referred to as "Toilet to Tap." The negative views on reusing water for direct or indirect potable use is largely attributable to lack of education and understanding of the treatment processes involved, as all municipal water treatment plants are legally required to meet stringent effluent limits that meet the needs of the receiving source. To help residents and opponents get over the

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[45] *Water Market USA 2011* (GWI).
[46] *Water Market USA 2011* (GWI).

psychological hurdle of drinking treated sewage water, San Diego offers tours of its Advanced Water Purification Facility. Visitors can get an up-close look at the facility's water treatment process, which includes microfiltration/ultrafiltration, reverse osmosis, and advanced oxidation with ultraviolet disinfection and hydrogen peroxide. At the end of the tour, visitors are encouraged to sample and compare existing drinking water and purified recycled water from the facility. Financing also serves as a barrier, as revenue generated from selling reused water is an important source of funds for utilities, but not enough by itself to support the investment. Utilities that rely on pricing to recover a portion (if not all) of the costs of implementing reuse within the wastewater treatment process are often limited by the basis of setting reused water rates at a percentage of drinking water rates. According to a survey conducted by HDR (a global EPC firm) in 2009, in which 26 US utilities participated, nearly 70% of respondents stated they were not able to cover 100% of annual operating costs via sales revenue from reused water.[47] These figures are strikingly similar to an AWWA survey in 2007, which showed nearly 75% of respondents unable to recover full operating costs through reused water revenues. While pricing reused water below that of drinking water may or may not help to overcome the public perception barrier and encourage its use, passing the entire cost of reused water through to customers would indeed be directly prohibitive to its use. To promote reuse, municipalities may award subsidies that enable utilities to justify investment in reuse technologies. For example, the Metropolitan Water District in Los Angeles, California disburses up to $0.17 per m^3 of reused water manufactured and utilized within its members' jurisdiction, thus posing the double benefit of receiving a subsidy and not having to purchase costly water from the MWD.[48] Some utilities may wish to rely on government bonds like the Clean Water State Revolving Fund programs to fund their reuse upgrades. However, only 1% of the $74 billion in financing provided through FY2009 has gone towards stormwater/recycled water projects.[49]

In the seven year span from 2009 to 2016, the global installed capacity of high quality water reuse plants is expected to experience an 18% compound annual growth rate, growing from 31 million

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[47] *Municipal Water Reuse Markets 2010* (GWI).
[48] *Municipal Water Reuse Markets 2010* (GWI).
[49] http://water.epa.gov/grants_funding/cwsrf/upload/2009_CWSRF_AR.pdf

m^3/d to 79 million m^3/d.[50] When capacity of high quality water reuse plants is combined with that of lower quality water treated to no more than secondary level (typically used for irrigation, cooling purposes, and similar applications), total design capacity of the sector is estimated to grow from 50 million m^3/d to 135 million m^3/d globally.

8.1.1 Industrial Reuse

Industrial water reuse is also gaining a significant amount of popularity, as increasingly stringent effluent quality limitations are forcing companies to invest higher dollars in advanced treatment solutions such as advanced membrane systems, disinfection equipment and specialty chemicals. Additionally, as limited water resources are starting to make fresh water more expensive, the benefits of reuse are becoming more and more apparent. The power generation industry in particular is exploring the concept of water reuse, as cooling systems use millions of gallons of water a day. In 2008, water-cooled thermoelectric power plants withdrew 60 billion to 170 billion gallons (180,000 to 530,000 acre-feet) of freshwater from rivers, lakes, streams, and aquifers every day, and consumed 2.8 billion to 5.9 billion gallons (8,600 to 18,100 acre-feet) of that water.[51] To address this excessive water usage, power plants are increasingly looking to reuse water and to replace existing technology with more water-efficient technologies. Though in reusing water, industries must keep in mind the variability of constituents from one water source to the next (to avoid mineral scaling, corrosion, or microbiological growths in its systems), as well as the effect of salinity on effluent toxicity.

Another industry gaining much attention for its usage of freshwater and subsequent production of wastewater is the oil and gas industry. This sector has grown immensely over the past few years, and is expected to remain one of the fastest growing markets for water technology going forward. According to Chrysalix Energy Venture Capital, oil and gas wastewater treatment presents one of the largest near-term water opportunities, as companies in the sector are faced with a defined problem and are noticeably eager to find a solution. In particular, it is the advent

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[50] *Municipal Water Reuse Markets 2010* (GWI).
[51] Averyt, K., J. Fisher, A. Huber-Lee, A. Lewis, J. Macknick, N. Madden, J. Rogers, and S. Tellinghuisen. 2011. Freshwater use by U.S. power plants: Electricity's thirst for a precious resource. A report of the Energy and Water in a Warming World initiative. Cambridge, MA: Union of Concerned Scientists. November.

of hydraulic fracturing, which is the process of using a pressurized fluid to fracture rock layers in order to release petroleum, natural gas, coal seam gas, or other substances for extraction, that is propelling the reuse market forward in this industry. The process uses an immense amount of water and poses potential environmental, health, and safety risks, leading it to be suspended or banned in various states throughout the US. Water companies have identified this sector as a huge market opportunity, and have begun to introduce treatment technologies that address the unique effluent qualities of produced water. For example, Latitude Solutions, a Boca Raton, FL-based company, utilizes electro-precipitation technology to remove heavy metal ions, charged colloids, emulsions, and microorganisms present in oil and gas streams, while FilterBoxx, a Canadian company, uses combinations of reverse osmosis, nanofiltration, green sands, clarifiers, and desalination systems to treat produced water via mobile units.

8.2 Policy and Regulation

There are currently no federal regulations directly governing water reuse practices in the US, guidelines are increasingly being built into legislation to preserve high standards of public health and sustainable living environments. Various states have, however, developed regulations specific to reused water quality and treatment requirements. To date, 25 states have regulations in place and 16 states have adapted guidelines or design standards, while 9 states have no regulations. An extremely common water quality standard in the US is the "Title 22" standard from Chapter 4 of the California Code of Regulations, which defines standards for various beneficial uses of reused water.

The standard is known to be the strictest classification standard in existence, and as a result, is used as the basis for regulations in other states throughout the US, and was even reportedly used as a basis to draft a Canadian code on water reuse. To become Title 22-certified, technology vendors must install and test their system(s) for approximately 3-6 months and demonstrate compliance with Title 22 requirements. Title 22 certification testing can be conducted by a variety of parties, including engineering firms (e.g., MWH, who confirmed compliance for Meurer Research's MeurerMBR) and university research labs (e.g., North Carolina State University, who confirmed compliance for Anua's PuraM MBR). California, which is widely regarded as a leader in developing the regulatory landscape, is also drafting regulations for Groundwater Replenishment with Recycled Water.

Also, wastewater treatment is becoming less and less of an option for utilities and industries in light of increasingly stringent environmental discharge regulations, lending to the rise in popularity of water reuse. For instance, the National Pollution Discharge Elimination System (NPDES) under EPA subjects municipal and industrial wastewater to varying permitting requirements and discharge limitations based on location of discharge (e.g., sanitary sewer, storm drain, or septic system) and local guidelines in existence. In addition, depending on the type of industrial or commercial facility in operation, more than one NPDES program may apply. NPDES permits do not apply to the practice of reuse unless the treated wastewater is used to augment a receiving body of water. As indirect or direct potable reuse gains more traction, regulations under the Safe Drinking Water Act, which apply to every public water system in the United States, will also become relevant.

8.3 Technologies

8.3.1 Products

Technologies used in the reuse market do not differ from those already used in the drinking water and wastewater treatment markets. To meet specific reuse requirements engineering design firms typically develop customized treatment solutions through unique technology combinations. Combinations vary based on characteristics (contaminants) of inflow, final water quality requirements, end use of effluent, peak flow requirements, regulatory requirements, and cost constraints, among other metrics. The most popular technology combination includes microfiltration, reverse osmosis, and membrane bioreactors/advanced oxidation. It is expected that this three-stage treatment process will ultimately (in the next ten years) become a standard for the water reuse industry.

The overlap in technologies with the drinking water and wastewater sectors has served to fuel additional sector growth. Public perception of water reuse remains relatively low, but customer confidence in certain technologies (i.e., ultrafiltration, reverse osmosis, UV) is rising. The use of proven technologies provides customers with a certain level of reassurance in the ability to treat water to a point where it can be blended in reservoirs or aquifers for potable purposes. As the microfiltration and reverse osmosis membrane markets were already covered in Section 4, the technology overview for reuse will focus on innovation within the membrane bioreactors/ advanced oxidation segment.

Membrane bioreactor (MBR): MBRs were first introduced to the wastewater treatment market in the 1970s, and are now positioned as one of the most promising technologies for water reuse applications. The technology, which was originally used for desalination, consists of a membrane process combined with a suspended growth bioreactor. MBRs are favored for reuse applications because of their ability to produce high quality effluent fit to be discharged to coastal waterways or used for urban irrigation. However, membrane fouling (and subsequent costly replacement of membranes) presents a major drawback. Fluid mixing within an MBR plays a major role in controlling membrane fouling, but also contributes to high energy consumption.

Advanced oxidation (AO): AO is widely used for reuse applications because of its ability to drastically reduce or completely eliminate contaminants associated with public health and environmental concerns, such as endocrine disruptors. Yet, the process is known to generate byproducts, such as bromate and bromite, as a result of introducing ozone into the wastewater treatment process. For this reason, UV technology, a costly alternative, is often introduced to break down chemical bonds of contaminants. There are reportedly about 15 full-scale remedial applications of the UV/oxidation process in operation right now, with most of them for groundwater contaminated with petroleum products or a variety of industrial solvent-related organics (e.g., TCE, DCE, TCA, and vinyl chloride).[52] Further testing on pilot and/or full-scale installations would help to further understand benefits and effectiveness of the combined solution.

[52] http://www.frtr.gov/matrix2/section4/4-45.html

8.3.2 Services

Reuse projects are commonly owned and operated by municipalities, but there are multiple firms that focus on the development, application, and design of wastewater treatment and reuse facilities. Examples of these firms include AECOM, Black & Veatch, CDM, CH2M Hill, and MWH. Veolia has noted that reuse is of special interest to the firm due to the high margins achievable given the level of customization required for each project. As a result of financing barriers, consulting engineers are also increasingly being brought onto projects in a Design-Build capacity. This approach is also popular in international markets where large companies self-finance projects and then recover money through the rates charged for the treated and distributed water.

8.4 Vendor landscape

The reuse market materialized from existing wastewater treatment processes. With equipment and services commonly shared between wastewater treatment projects and reuse projects, there are few, if any, players exclusively devoted to water reuse.

Current market leaders for providing reuse systems are GE Water, ITT's newly formed Xylem, Siemens Water Technologies, and Veolia, all of who have prioritized reuse within their business. Key component suppliers include Memcor (Siemens), Norit, and Pall/Asahi, all of who supply UF/MF membranes, and Zenon (GE), Memcor (Siemens) and Kubota, all of who supply MBR systems. Not only will typically risk-averse customers be more apt to use one of these trusted technology brands, but global companies like these may help to reduce costs associated with water reuse through achieving economies of scale.

Within the US, reuse is gaining the most attention in drought-prone areas that are dependent on non-renewable groundwater resources. States like California, Texas, Florida and Arizona, all of which are current leaders in the reuse of water for agricultural purposes, have all strongly considered wastewater-to-drinking-water systems as a result of long droughts that are increasingly believed to become long-term problems due to global warming effects. In the Southwest region especially, lack of rainfall has made reuse an attractive long-term solution, as it remains a financially attractive alternative to desalination. The largest system in the US is Southern California's $480 million Groundwater Replenishment System, which provides reused water to more than 100,000 Orange County families.[53]

8.5 Venture activity

Investment in companies that provide tertiary or advanced treatment technologies, which could be used for treating reused water to drinking water quality, has been relatively healthy in the last few years. Global VC funding in the reuse sector increased 16% to $33.4 million in 2011 from $28.7 million in 2010. Bluewater Bio, a provider of wastewater and sludge treatment services using biological technologies, received two separate rounds of funding, in addition to an $8 million revolving convertible debt facility. Separately, companies have also found funding in the private placement market, as companies like United Envirotech, a provider of membrane-based treatment solutions, received a $113.8 million investment from Kohlberg Kravis Roberts (KKR) in the form of a bonds issue.

Venture activity in the reuse market is difficult to capture as few companies (if any) are strictly focused on reuse. VC firms, however, do acknowledge the market opportunities that exist within reuse, and are increasingly on the lookout for new technologies that can be applied in the sector. According to XPV Capital Corporation, the reuse market presents scalable opportunities and North America is expected to be one of the largest reuse markets, ahead of other parts of the world. Another firm, Kinrot Ventures, expects the reuse market to continue to grow primarily within the agricultural and industrial markets in the near term, with potential to shift to direct or indirect potable use in the long term. The firm views pricing of water to be a somewhat influencing factor in growing the wastewater-to-drinking-water market, but views the public's psychological barrier as being more difficult to overcome. These views are somewhat consistent with those expressed by Ecomundi Ventures, who also finds the industrial market to be more

[53] http://www.wired.com/science/planetearth/multimedia/2008/01/gallery_sewage_plant

attractive than the municipal market, but cites shorter time frames for technology adoption and relatively faster returns on equity as reasons for growth.

The companies below have developed some of the more recent technologies that have the potential to impact and propel the reuse market, and are believed to be the latest innovators within the space

Company	Country	Description	Capital raise	Round
United Envrotech	Singapore	Provider of membrane-based water and wastewater treatment and reclamation solutions, in addition to EPC and O&M services.	$113,800,000	Private Placement
Latitude Solutions	USA	Provider of products, processes and solutions for contaminated water remediation in industrial applications.	$17,991,567	Private Placement
Bluewater Bio	UK	Provider of wastewater and sludge treatment services using biological technologies.	$8,000,000 $6,100,000 $3,250,000	Structured Debt Growth Equity Growth Equity
Triton Water	Singapore	Assembles and installs water treatment modules ranging from low-energy desalination, to water management and wastewater systems.	Undisclosed $15,000,000	Series B Series A
Filterboxx	Canada	Supplier of containerized water treatment systems to industrial, municipal, resort and aboriginal clients.	$9,000,000 Undisclosed	Growth Equity Growth Equity
Hangzhou Dingchu Technology	China	Energy conservation and water recycling business.	$4,400,000	Series A
AquaMost	USA	Developer of an advanced oxidation technology that uses ultraviolet radiation to activate a titanium dioxide (TiO_2)-based photoactive electrode.	$3,000,000 $1,000,000	Series B Research Grant
M2 Renewables	USA	Developer of filtration process to obtain irrigation-quality, reusable water directly from raw sewage.	$3,000,000	Growth Equity
Pasteurization Technology Group	USA	Developer of combined renewable energy generation and wastewater disinfection for reuse systems.	$1,000,000	Series A
Geo-Processors	Australia	Developer of proprietary saline water treatment technology that enables wastewater minimization through product recovery and water reclamation.	$1,000,000	Seed
AquaPure Technologies	Israel	Developer of an advanced oxidation technology for water treatment with focus on MTBE treatment, metal removal and site remediation.	$720,000	Growth Equity
Advanced Hydro	USA	Developer and provider of membrane based solutions for water reclamation, desalination, and general treatment.	$500,000	Seed
GeoPure Hydro Technologies	USA	Developer of technology that purifies and recycles contaminated exploration and production wastewater.	Undisclosed	Series A
APTwater	USA	Developer of water treatment technologies and provider of operating services, targeting a wide variety of contaminants and applications in industrial and water and wastewater.	Undisclosed	Series A

8.6 Company Profiles

- APTwater
- M2 Renewables
- Pasteurization Technology Group

9 Nutrient Recovery

With recognition of the value resources within wastewater streams, effluent is no longer being seen as solely a disposal issue. Numerous methods for recovering these resources are emerging and they target both (1) energy recovery, where wastewater sludge can be removed to serve as a source for renewable energy generation. And (2) nutrient recovery, concerning the capture of biosolids from wastewater, which can be composted, packaged, and sold as fertilizer or soil conditioners. As approaches to energy recovery have been around for years, this report focuses on very recent attempts to recover key nutrients. Key market drivers and challenges for the nascent nutrient recovery market are highlighted below:

Drivers	• Regulatory driver – nutrient discharge limits • Economic driver – increased revenue through new revenue stream or reduced energy costs • Economic driver – extraction of certain nutrients from wastewater streams may be cheaper than extracting from nature • Economic driver – removes cost of sludge disposal • Operational driver – dissolved nutrients can clog piping systems
Challenges	• Regulatory challenge – nutrients extracted from wastewater may be viewed as waste and subject to unique regulations • Social challenge – negative public perception of using biosolids as fertilizer • Market challenge – complex decision-making processes with municipalities

9.1 Market

Today, the total wastewater management market in the US is estimated at $1.2 billion, growing at a 5.8% CAGR to roughly $1.6 billion by 2016.[54] Wastewater management covers a broad range of activities, including sludge digestion, thickening, dewatering, thermal processing, reuse, and ultimately, disposal. Included in this market estimate are both utility and industrial users, in addition to energy recovery technologies that focus on the production of biogas and alternative fuels from sludge.

Narrow our focus to only the nutrient recovery market, eliminating energy recovery and general sludge disposal markets, we see a nascent industry just beginning to deploy new technologies. Based on our review of vendors engaged in nutrient-recovery-for-fertilizer projects and pilots, we estimate the current market to be only ~$10 million. While the market is small, we are bullish on prospects for nutrient recovery technologies and anticipate high market growth due to several factors.

One of the biggest growth drivers of the nutrient recovery market is its ability to generate an additional revenue stream for wastewater treatment plants, as technology vendors often share a portion of revenues from the commodity sales with their customers. A popular use of recovered nutrients is fertilizer, which is becoming increasingly expensive in the US, therefore posing an attractive revenue-sharing opportunity for wastewater treatment plants. Nutrients such as phosphorous, nitrogen, and ammonia are popular recoverable resources as they are both becoming scarcer in the atmosphere and are often without natural substitutes. One often cited example is phosphorus. Florida, which accounts for nearly 80% of the domestic production capacity of phosphate,[55] reportedly only has ~30 years of phosphate reserves left, indicating the nation's phosphate-based fertilizer industry could suffer if no new or innovative actions are taken.

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[54] *Water Market USA 2011* (GWI)
[55] http://www.epa.gov/radiation/tenorm/fertilizer.html

Further, the nutrient recovery market continues to gain traction as regulatory limits on nitrogen and phosphorus proliferate. EPA has imposed nutrient discharge limits in an effort to stem the detrimental effects on the environment of excessive nutrients in wastewater (e.g., promoting algae growth, affecting dissolved oxygen levels, and posing a threat to natural fish habitats). Nutrients can also pose problems for internal operations at a wastewater treatment plant. Plants that practice biological nutrient removal and anaerobic sludge digestion are particularly affected as they concentrate large quantities of ammonia and phosphorus in their sludge handling streams. These dissolved nutrients form struvite-scale in piping, pumps and valves, leading to plugging of the piping systems, which in turn leads to pumping inefficiencies, reduced system capacity, high operating costs, maintenance shutdowns, and pipeline failures.

Market growth may be slowed by a variety of market, regulatory, and site-specific challenges. Specifically, nutrient recovery vendors cited complex decision-making structures at municipalities as a barrier to industry growth. Decisions to adopt and implement new technologies can take years and work directly against the accelerated sales model most young companies aim to establish. While this concept is applicable to young companies in virtually any sector of the water & wastewater market, it is interesting to note that vendors in the nutrient recovery sector voiced this as a high priority challenge. Vendors often face cash flow challenges in working with conservative municipalities and their cumbersome decision-making processes. As a result, many companies have refocused efforts on the industrial sector, a secondary target market after municipalities that offers a greater growth opportunity.

As previously noted, the US market has been relatively slow and is currently "catching up" to the rest of the world when it comes to recovering nutrients from wastewater streams. Other countries have long treated nutrients as a form of pollution and therefore implemented regulations around nutrient discharge, while the US is in the initial phases of giving engaging with this concept. Additionally, some countries (e.g., Netherlands, Japan) impose high sludge treatment costs on utilities, further promoting the international growth of the nutrient recovery concept. For instance, Japan now has a full-scale demonstration of the Phosnix process, which enables phosphate removal and recovery from wastewater at the Ube Industries Sakai plant.

9.2 Policy and Regulation

The existence of excessive nutrients in receiving waterways is considered by EPA to be the single largest cause of water quality impairment in the US. As a result, limitations on certain nutrients (e.g., phosphorous, nitrogen) have been imposed on effluent discharge from wastewater treatment plants. While traditional wastewater treatment technologies remove nutrients to some degree, nutrient removal technologies help to ensure that any and all federal regulations (states do not establish their own maximum nutrient limits) relating to a specific nutrient are met. Water treatment plants are slowly becoming more aware of the economic benefits that nutrient removal technologies offer, as these technologies enable compliance with current and future regulatory limits.

Other relevant policies and regulations in the nutrient recovery industry include those around biosolids and fertilizers. Biosolids are heavily regulated in comparison to manures, fertilizers, and other yard waste composts, primarily due to the unpredictable presence of organic matter. They are separately regulated by EPA under the CWA (specifically, the CWA amendments of 1977 and 1987), which ensures safe and responsible management of biosolids, and the Ocean Dumping Ban Act of 1988, which prohibits dumping biosolids into the ocean. Also, the 40 CFR (Title 40, Code of Federal Regulations) Part 503 Biosolids Rule of 1993 governs the use and disposal of municipal sewage sludge. The quality requirements set within this rule are meant to promote public acceptance of biosolids as a soil conditioner or fertilizer.

Phosphorous-based fertilizers may also be regulated under fertilizer regulations, which vary on a state-by-state basis and are generally less stringent due to the consistent chemical makeup of fertilizers. For example, Ostara Nutrient Recovery Systems, a Vancouver, Canada-based company that produces fertilizer from municipal and industrial wastewater streams, falls under this category. The company's technology is able to produce consistent fertilizer no matter which waste stream is being treated. As a result, the company navigates fertilizer laws in every state and must register its product in each one separately.

9.3 Technologies

9.3.1 Products

Companies are increasingly developing technologies that can be applied to wastewater streams and foster the removal of solids, which are then sold as commodities. Many technologies rely on complex, high-energy processes, and as such are not widely accepted by utilities. Typically, the recovery of resources such as phosphate was done by adding chemicals to wastewater holding tanks and precipitating out the phosphate, while current innovation focuses on recovering these nutrients in a different, more saleable form.

Innovation is focused not only on the removal of nutrients, but also on the recovery of struvite, which is increasingly marketed as a high-value, slow-release fertilizer. While the market for struvite as a fertilizer product is not yet well-established, growth trials have been positive. In King's County, WA, for example, crop needs are matched with the nitrogen value of biosolids, resulting in enhanced crop yield and reduced soil erosion. The County has so far found that biosolids have improved the germination rate of wheat, thereby improving winter survival of young wheat plants.[56] However, the fertilizer product may have to overcome some regulatory hurdles as products from wastewater may still be viewed as waste, and therefore subject to unique rules.

Fluidized bed reactor (FBR): FBRs are undergoing increasing use in the Resource Recovery sector due to their ability to generate struvite in a controlled and reliable way. The process beings with the addition of chemicals to a wastewater stream to form struvite crystals, which combine to form pellets. Treated wastewater is then removed, leaving behind the struvite pellets, which continue to grow and are later harvested for fertilizer. This crystallization process has proven to be a simple and promising process for utilities.

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56 http://www.kingcounty.gov/environment/wastewater/Biosolids/BiosolidsRecyclingProjects/BoulderPark.aspx?print=1

Physical-chemical: Physical-chemical technologies rely on separating dissolved phosphorous from sludge via precipitation. As technologies differ in their approach involving the use of various chemicals and/or processes such as ion exchange, final products are also varied. Phosphorous can be recovered as struvite, phosphoric acid, or iron phosphate.

Vitrification: Vitrification is the process of combusting sludge in a chamber with air. Upon melting, the sludge turns into molten glass, leaving behind silica and other inorganic matter. A heat recovery system will collect the gases created as a result of the combustion, while the glass is drained into a quenching tank. This process is known throughout the water industry, but no known technology vendors exist.

9.3.2 Services

Municipalities interested in nutrient recovery frequently contract with engineering firms who aid in the analysis and design of recycling and waste management programs. These independent engineering firms work closely with equipment vendors to understand and approve nutrient recovery technologies, and then endorse solutions to the municipality. Major engineering firms include CH2M Hill, Black & Veatch, and Carollo. EPC firms, such as Veolia and Suez, are typically only brought in for big projects that include nutrient recovery as one of multiple initiatives.

Other services related to nutrient recovery include the operation of the struvite system, its ongoing maintenance, and subsequent transportation and delivery of the end fertilizer product. Though, wastewater treatment plants typically opt to train internal staff members to run the systems, rather than contracting out to consulting or engineering firms. In addition, system vendors largely offer proprietary maintenance services, and take care of the marketing and distribution of the fertilizer. While wastewater treatment plants will pay a monthly fee for ongoing use of the struvite system, they also enter into a revenue-sharing agreement with the system vendor for any money generated from the sale of fertilizer. The structure of business models currently in place leaves little room for outside service revenues.

9.4 Vendor landscape

Due to the market's relative nascence, many companies are still in the pilot/product development phase and there are no established leaders as of yet. One of the more indicative ways to analyze the market, therefore, includes looking at total capital raised. In this regard, market leaders in North America (by disclosed amount of capital raised) are ThermoEnergy (Little Rock, Arkansas), Ostara Nutrient Recovery Systems (Vancouver, Canada), and Aquarius Technologies (Port Washington, Wisconsin). The majority of equipment vendors within the global nutrient recovery market are located in the US, with a minor presence in Israel and Canada.

Some of these companies invested significant amounts of money into resource recovery technology that was not accepted by the market. For example, ThermoEnergy had a licensing agreement with Battelle Memorial Institute for the institute's Sludge-to-Oil-Reactor System (STORS). The process proved to be overly complex in pilot testing and energy requirements were substantial, limiting ThermoEnergy's ability to capitalize on the product's otherwise successful results. Ultimately, ThermoEnergy dropped the product from its portfolio.

These types of experience show that companies can claim a competitive advantage when capital and operating costs are kept down; companies need to ensure that manufacturing costs are less than the value of the final product.

9.5 Venture activity

While total VC activity has fallen 8% to $35.5 million in 2011, from $38.4 million in 2010, companies in the resource recovery sector are attracting higher dollars per round than companies providing water monitoring and metering solutions. Energy recovery is an increasingly popular theme in wastewater treatment, though investments tend to favor companies that develeop nutrient recovery technologies. The following chart higlights funding within the resource recovery sector since 2009.

Company	Country	Description	Capital raise	Round
Glori Energy	USA	Developer of the AERO™ (Activated Environment for the Recovery of Oil) System to increase oil recovery from water flooded oilfields.	$20,000,000 $16,000,000	Series C Series B
BCR Environmental	USA	Provider of water and wastewater treatment solution based on biosolid treatment methods.	$10,000,000	Series A
Emefcy	Israel	Developer of Electrogenic Bioreactors that treat wastewater and generate electricity.	$4,000,000 $5,000,000 Undisclosed	Series B Series A Seed
ThermoEnergy	USA	Developer of technologies for removing nitrogen from wastewater streams, converting sewage sludge to a fuel, and a clean coal system.	$2,630,000 $1,250,000 $5,000,000	Private Placement Private Equity Private Equity
PhosphonicS	UK	Developer of a technology to recover precious metals from process, waste and effluent streams.	$5,300,000	Follow-on
Aquarius Technologies	USA	Developer of technology for preventing the generation of waste sludge during wastewater treatment.	$4,000,000	Series B
Simbol Materials	USA	Developer of a process for removing silicates from geothermal wastewater via precipitation and filtration.	$1,375,000	Structured Debt
MAR Systems	USA	Developer of proprietary adsorbent media that removes heavy metals (e.g. mercury, selenium, chrome, arsenic) from aqueous streams.	$1,137,190	Seed
Pasteurization Technology Group	USA	Developer of combined renewable energy generation and wastewater disinfection for reuse systems.	$1,000,000	Series A
Ecochemtec	Israel	Developer of sedimentation technology to produce high value chemicals from seawater desalination plant waste.	$500,000	Seed
Hydrospin	Israel	Developer of inside pipe generator that supplies electricity for water monitoring and control systems.	$500,000	Seed
Liberty Hydrologic Systems	USA	Developer of proprietary technology to remove selenium from water.	$500,000	Seed
Pilus Energy	USA	Developer of scalable Electrogenic Bioreactor (EBR) platform to convert industrial wastewater into value.	Undisclosed	Private Placement
BlackGold Biofuels	USA	Developer of a patented process to convert grease from wastewater streams into biodiesel.	Undisclosed	Series A
Algal Scientific	USA	Developer of advanced wastewater treatment systems using proprietary algal strains, which also produce biomass as a byproduct.	Undisclosed	Seed

9.6 Company Profiles

- ThermoEnergy
- Ostara Nutrient Recovery Systems
- Multiform Harvest

10 Distributed Small Water Facilities

For purposes of this discussion, small water facilities are defined as those with flow rates lower than 100,000 gallons per day. EPA estimates that there are nearly 43,750 public water facilities that serve a population of 3,300 people or less, and just over 4,210 public water facilities serving a population of 10,000 people or more.[57]

10.1 Market

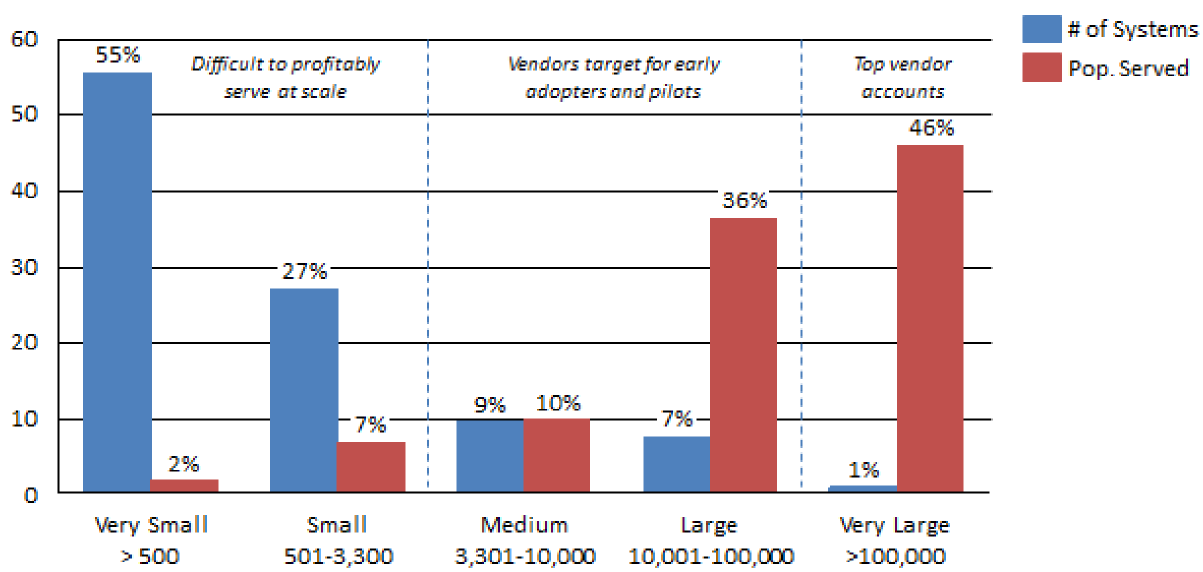
A primary difference between different sized water treatment plants is the source of water. Small drinking water facilities rely on wells and surface water, where multiple treatment technologies are often required to treat the unique contaminants present in each source. Due to the smaller pools of water that run through the plant, rainfall and other events have relatively large impacts, and influent rate and quality can vary significantly on a day-to-day basis. Also, there is a higher emphasis on groundwater reuse and sewer mining, where smaller plants take treated water from larger plants and treat that effluent to potable standards. This trend is mostly driven by previously discussed water scarcity and social responsibility concerns. Sludge is typically transported back to larger plants for treatment and disposal. From an operational standpoint, most treatment technologies in small water facilities can be run on a part-time basis due to the lower flow rates. These technologies are typically packaged differently for smaller facilities than larger facilities, in that they can be constructed of lighter weight material (e.g., steel) and delivered as preassembled solutions. In contrast, larger treatment plants typically install permanent treatment technologies in concrete bases, leading to higher construction and engineering costs. Additionally, the large plants are held to more stringent regulations due to the impact their larger flows have on receiving bodies of water (as related to wastewater discharge). From a regulatory standpoint, these facilities are held to the same standards when it comes to

[57] EPA 2011. Fiscal Year 2010 Drinking Water and Ground Water Statistics. EPA Office of Ground Water and Drinking Water. EPA 817K11001, June 2011.

quality of drinking water. Effluent standards at wastewater facilities, however, differ between small and large plants, as explained in Section 10.2.

When examining how equipment vendors approach asset owners as potential customers, it is critical to consider the size of drinking water facilities and the dynamics of serving these facilities. EPA categorizes drinking water systems into five categories by size from Very Small to Very Large. The following chart illustrates the markedly inverse relationship between population served and size of system for community drinking water systems (these systems cover 90%+ of America's population). According to the data, 82% of the population is covered by only 8% of the country's water systems (approximately 4,100 of 52,000 systems).[58]

<u>Vendor Dynamics By Community Drinking Water Systems: By Size, % of Systems, % of Pop.</u>



Source: 2010 EPA Factoids, Cleantech Group Analysis

For many vendors, municipal water utilities are the last customer segment to be addressed given their notoriously slow procurement and certification processes. Water innovators are attracted to customers with sufficient scale to drive revenue at a reasonable cost of sales and service.

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[58] *Fiscal Year 2010 Drinking Water and Ground Water Statistics* (EPA). http://water.epa.gov/scitech/datait/databases/drink/sdwisfed/upload/new_Fiscal-Year-2010-Drinking-Water-and-Ground-Water-Statistics.pdf

Consequently, many equipment vendors find the fragmented Small or Very Small systems market as difficult and unattractive. Most innovators will look to larger systems to pilot technologies. Medium and Large facilities are ideal early adopters as they have sufficient scale for vendors to serve profitably, but may be able to move somewhat more nimbly than the largest of systems to adopt new technologies, though this is not uniformly the case. In general, for first adopters and pilots, early stage vendors will look for systems that meet a size threshold and that have the lowest sales friction. The ~400 Very Large systems that cover 46% of the population are key accounts for any vendor; they are the long term target market for vendors hoping to become major forces in the drinking water market.

10.2 Policy and Regulation

Drinking water standards do not differ for treatment plants based on flow rates or size of population served, and wastewater discharge regulations have typically been more stringent for large treatment plants due to the impact their larger flows have on receiving bodies of water. Recently, however, distributed small water facilities have expressed that Total Maximum Daily Loads (TMDLs), which are the maximum amount of a pollutant that bodies of water can receive and still safely meet water quality standards, are becoming burdensome from both a financial and environmental standpoint. These limits require a high level of local involvement for activities such as the development, submission, and approval of a Watershed Implementation Plan and the allocation of nutrient reduction goals to counties and small watersheds. Though the local-level focus and details are necessary to address many of the decisions that contribute to nutrient pollution (e.g., planning and zoning actions; stormwater management; erosion and sediment control programs; septic system regulations; ordinances regulating lawn fertilizer, etc.), tough economic conditions and budget cuts are affecting the ease with which localities can address EPA limits.

10.3 Technologies

10.3.1 Products

While the underlying treatment technologies do not differ largely based on flow rates, packaging and delivery of technologies vary based on expected usage. Smaller facilities do not require permanent solutions that run on a full-time basis, and therefore have the ability to opt for preassembled units that are available at a lower cost. Additionally, in some cases smaller facilities have more control over the water sources accessed, resulting in higher quality influent. With this increased quality of water, simpler disinfection methods such as chlorine are sufficient, and the need for multiple treatment technologies is avoidable. For small water facilities, solutions can also often be directly joined to wells that serve as a main water source in order to treat the specific contaminant(s) present in that stream.

10.3.2 Services

The value chain for distributed small water facilities does not differ significantly from that outlined for municipal wastewater (and reuse) facilities. The presence of distributed small water facilities is believed to be on the rise, despite the last 30-40 years focusing on developing and serving larger plants that large EPC firms tend to target. This is expected to result in an increase in the number of local engineering design firms, as they maintain a deep understanding of the specific regions that will be served by the small water facilities. While the majority of requests from small water facilities will be serviceable by these small, local EPC firms, the option to subcontract resource-intensive work (e.g., feasibility analyses) to larger firms always exists.

10.4 Vendor landscape

As previously noted, treatment technologies do not differ for smaller plants and larger plants. However, distributors are often required to package and deliver their solutions differently based on the different target customer. Siemens, for example, will tailor membrane solutions for large facilities that serve nearly 100,000 people, and small facilities that serve no more than 10,000 people. As such, the vendor landscape for small water facilities closely matches that of Filtration, Disinfection, and Water Reuse.

Vendors tend to offer solutions that serve a specific market segment (e.g., municipalities), but some may attempt to bridge together multiple markets (e.g., residential and commercial markets). Large technology vendors have the ability to package their solutions for smaller users, but some often lack the resources necessary to understand unique market dynamics and to effectively compete with smaller, more experienced vendors. The large upfront investment required for large vendors to enter regional markets can delay expected returns by 3-4 years, at least, and serve as a barrier to entry.

10.5 Venture activity

As explained above, venture landscape for small water facilities is expected to include all the same companies mentioned in Disinfection, Membrane/Filtration, and Reuse. For information on venture investments within each of those sectors, please refer to the corresponding chapter sections.

10.6 Company Profiles

- Anua
- Puralytics

11 Green Infrastructure / Wet-Weather Flow

Billions of dollars are spent annually on big pipe systems to prevent combined sewer overflows, as these pipes can be even costlier to replace when faced with EPA consent decrees. Stormwater management strategies such as green infrastructure and other low impact development (LID) techniques also reduce future water infrastructure needs, and can result in financial savings to communities. Cities have recently begun to acknowledge these benefits and green roofs, rain gardens, permeable pavement, and similar solutions are becoming more common as methods of wet weather overflow management. Key market drivers and challenges are highlighted below:

Drivers	• Regulatory driver – EPA consent decrees for violating CWA • Economic driver – money savings to communities • Social driver – helps avoid negative public attention associated with closing of public beaches, parks, etc.
Challenges	• Market challenge – lack of data to demonstrate effectiveness and promote understanding of benefits • Economic challenge – expensive projects with long timelines • Social challenge – runoff may be richer in nitrogen and phosphorus • Regulatory challenge – rainwater harvesting largely unaddressed by enforceable regulations and codes, leading to use of overly stringent graywater requirements

11.1 Market

For the purposes of market sizing, we have restricted our view to municipal construction/retrofit projects specifically designed to reduce wet weather waterflow.[59] An examination of some of the largest and smallest cities in the US and their estimated spend on green infrastructure initiatives leads us to estimate the current market at $600-750 million in municipal spending. Services comprise about 50% of this tally and consist of design and engineering costs, landscaping, labor, mobilization costs, and project contingencies. The other 50% is largely made up of construction and landscaping materials such as permeable pavement, sand beds, ponding areas, planting soils, and plants.

We expect the green infrastructure market to grow at a somewhat slow pace, as many of the cities and communities undertaking green infrastructure initiatives are not yet doing so out of a proactive desire to manage stormwater. In fact, the market is largely driven by EPA consent decrees relating to combined sewer overflows (CSOs) that are in violation of the Clean Water Act. A CSO, which is the discharge of untreated wastewater and stormwater into local waterways, is

[59] To include all public/private construction projects that incorporate elements of waterflow design would encompass the majority of the US construction market.

caused when combined stormwater and wastewater management facilities become overburdened (i.e., after rainstorms). This is largely due to urban areas being dominated by hard, nonporous surfaces that contribute to heavy urban runoff, defined as rainfall that travels over roofs and the ground, picking up various contaminants (e.g., soil particles, heavy metals, organic compounds, animal waste, oil and grease). EPA estimates that there are over 770 CSO communities throughout the US, mostly concentrated in older regions such as the Northeast and Great Lakes regions, with a smaller presence in the Pacific Northwest.[60] Another driver of the green infrastructure market is the growing concern around climate change. For cities predicting more rainfall, the need to implement more solutions has become increasingly apparent.

There are numerous headwinds that are slowing growth in the market. A primary reason is the short track record of low impact development in urban planning, resulting in a lack of performance data that can demonstrate its effectiveness in different environments. Additionally, this inexperience with green infrastructure initiatives extends to governments, institutions, and individuals, causing projects to potentially incur high costs and long timelines. While some of the publicly available case studies and pilot programs have demonstrated a 25-30% reduction in costs associated with site development, stormwater fees, and maintenance for residential developments that use LID techniques,[61] cities continue to worry about high design and construction costs and greater expenses from increased use of on-site landscaping material.

The North American market for green roofs is considered to be immature when compared to other regions of the world. For example, the European green roof market is relatively well-established due to government legislative and financial support (at both the state and municipal levels). As the benefits of green roof technologies become better understood, it is expected that the North American market will grow.

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[60] http://cfpub.epa.gov/npdes/cso/demo.cfm
[61] *Introduction to LID*. http://www.lid-stormwater.net/background.htm

11.2 Policy and Regulation

The move to incorporate green infrastructure initiatives within cities has so far been largely driven by EPA consent decrees. Communities are, however, increasingly choosing to undertake green infrastructure projects (especially in the event of a new construction project), even in the absence of EPA mandates. Federal development and redevelopment projects are subject to strict stormwater runoff requirements under Section 438 of the Energy Independence and Security Act of 2007. Specifically, Section 438 "requires federal agencies to develop and redevelop facilities with a footprint that exceeds 5,000 square feet in a manner that maintains or restores the pre-development site hydrology to the maximum extent technically feasible."[62]

Rainwater from rooftops can be collected and stored for reuse rather than reentering the water cycle through groundwater recharge. Although a few states and local jurisdictions have developed standards or guidelines for rainwater harvesting, it is largely unaddressed by enforceable regulations and codes. Building and plumbing codes are largely silent on the subject, with neither the Uniform Plumbing Code 3 (UPC) nor International Plumbing Code (IPC) directly addressing rainwater harvesting in their potable or stormwater sections. Consequently, graywater requirements are often used to govern rainwater harvesting systems, resulting in requirements that are more stringent than necessary. Codes should instead define rainwater harvesting and establish its position as an acceptable stormwater management/ water conservation practice.

Stormwater harvesting, on the other hand, is defined as the water collected from roads, drains, and parks (as opposed to being collected from roofs). A similar lack of uniform national guidance around stormwater reuse has resulted in differing use and treatment guidelines among state and local governments, presenting an impediment to the market. Some jurisdictions require stormwater to receive some level of treatment before being discharged directly into waterways. Treatment requirements are ultimately based on exposure risks, with risk of bacterial exposure

[62] "Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act". EPA, December 2009. http://www.epa.gov/owow/NPS/lid/section438/pdf/final_sec438_factsht.pdf

determining the most stringent levels of treatment. For example, Texas promotes harvested rainwater for any use including potable uses provided appropriate treatment is installed. For non-potable indoor uses, the state requires filtration and disinfection. Portland, Oregon, like many other jurisdictions, generally recommends rainwater use for non-potable applications such as irrigation, water closets, and urinals. Portland requires filtration for residential non-potable indoor uses, but requires filtration and disinfection for multi-family and commercial applications. A recent memorandum of understanding from the City and County of San Francisco, California, allows rainwater to be used for toilet flushing without being treated to potable standards.

11.3 Technologies

11.3.1 Products

Cities invest millions in green infrastructure, with common solutions including green roofs, permeable pavements, gravel ditches, and retention basins. Other technologies that play a role in green infrastructure include moisture sensors and soil probes (to measure infiltration), roof flow measurements, and flow meters.

Green roofs: One of the most popular solutions to stormwater management is green roofing. The addition of vegetation and soil to roof surfaces can lessen several negative effects of buildings on local ecosystems and can reduce buildings' energy consumption through temperature moderation. Additionally, living, or green, roofs can increase sound insulation and fire resistance, and prolong the longevity of the roof. Most importantly, green roofs can mitigate stormwater runoff from exposed surfaces by collecting and retaining precipitation, thereby reducing the volume of flow into stormwater infrastructure and urban waterways. Communities are becoming more aware of these benefits and are more open to the idea of incorporation of green infrastructure in new builds and upgrades to existing infrastructure. The energy savings and prolonged roof life can serve to make green roofs more economical than conventional roofs over the life span of the roof. Sedum is the most commonly used genus for green roofs.

Factors affecting the rate of stormwater runoff (and therefore the quality of green roofs) include the depth of substrate, slope of roof, type of plant community, and rainfall patterns. According to one study, green roofs reduce total building runoff by 60-79% on an annual basis.[63] Leaching from substrate, however, may result in runoff rich in nitrogen and phosphorus, resulting in a new source of surface-water pollution. Reduced fertilization of green roof vegetation to decrease the presence of these nutrients or other organic matter, however, may harm plant growth or survival. A natural solution would be to instead select plants that optimize the uptake of nutrients and contaminants.

Soil moisture sensors: Soil moisture sensors estimate volumetric water content based on the soil's ability to transmit electricity (or dielectric constant), which is increased with the presence of water. Dielectric methods have gained acceptance in the market due to their nearly instantaneous measurements, automated readings on a continuous basis, and low maintenance requirements. The technology, though, is relatively expensive given its complex electronics. Additionally, the volume of soil that can be analyzed is often limited to a small radius around the sensor.

11.3.2 Services

As opposed to some of the other water sectors explored in this report, green infrastructure is a service-heavy industry. Rather than having a well-defined value chain of vendors, design engineers and implementers for each project, many players act as full-service contracting firms specializing in the design and installation of green roofs or other green infrastructure alternatives. These firms will buy various components from small suppliers and nurseries that serve a variety of architectural and landscaping needs. For example, CONTECH Construction Products is a civil engineering site solutions company. The company's UrbanGreen Grass Pavers solution can provide lightweight volume storage to increase retention capacity of a green roof and add aeration to the root zone for healthy plants, and its UrbanGreen BioMedia solution can provide essential soil properties to support plant growth on green roofs. CONTECH provides its product along with any engineering or installation services required.

[63] Kohler, M., Schmidt, M., Grimme, F.H., Laar, M., Paiva, V.L.A., and Tavares, S. 2002. Green roofs in Temperate climates and in the hot-humid tropics - far beyond the aesthetics. Environmental Management and Health. 13(4) 382-391

Other services include testing soil moisture and monitoring rain absorption rates to ensure green infrastructure is serving its purpose. These tests can be done by local engineering firms.

11.4 Vendor landscape

Engineering firms rely on testing and flow monitoring equipment provided by vendors like Campbell Scientific, Stevens Water, Hach, Teledyne Isco, Accuron, and ADS. Other component vendors include those that provide waterproofing membranes for green roofs (American Hydrotech and Barrett Company) and those that provide plants specifically for green roofs (Etera and Motherplants).

11.5 Venture activity

As this is primarily a service-driven sector that involves municipalities and engineering firms, there is no VC investment data to report.

11.6 Company Profiles

- Aquanomix
- Hydro International (UK)
- CSO Technik (UK)

12 Ballast Water

Ballast Water is the water that marine vessels intake at one coastal port and discharge at another in order to maintain stability during transit. Invasive species are being migrated from port to port through discharge of dirty ballast water, causing economic and environmental damage all around the world. Hundreds of thousands of jobs in fishing, recreation, and tourism in coastal economies depend on healthy, functioning coastal ecosystems. According to a Pew report, "invasive species are responsible for about 137 billion dollars in lost revenue and management costs in the U.S. each year." [64] As impacts cannot be contained specifically to the United States, or even to North

[64] Panetta, L. E. (Chair) (2003). "America's living oceans: charting a course for sea change." Electronic Version, CD. Pew Oceans Commission.

America, it is worthwhile to first analyze and understand the current state of global and federal policy and regulation before exploring the different facets of the ballast water market. Key market drivers and challenges are highlighted below:

Drivers	• Regulatory driver – if IMO 2004 Convention global regulations are passed and enforced, a strong market for ballast water treatment systems is anticipated • Social driver – even without regulations, some shipowners may purchase a system to appear more environmentally friendly (system costs will drive decision) • Technology driver – most treatment solutions have been adapted from trusted land-based water treatment technologies
Challenges	• Regulatory challenge – if IMO 2004 Convention global regulations fail, the market will falter • Economic challenge – IMO approval process can take up to 2 years and cost anywhere from \$350,000 - \$500,000. • Market challenge – to succeed, it is essential to have deep relationships within the marine industry

12.1 Market

Global sales of ballast water treatment systems generated an estimated \$37 million in revenues in 2010[65], and are expected to increase rapidly upon ratification of the IMO Convention. Based on a mid-2012 ratification (which indicates a mid-2013 enforcement), global sales are expected to reach approximately \$950 million by 2013.[66] Services for this sector are estimated to be approximately 200%, or \$1.9 billion, of the equipment market. The regulations put in place by USCG did not create an existing market for ballast water treatment systems as the discharged ballast water was not expected to meet any specific quality requirements. As with IMO Regulation D-1, the early ballast water management regulations that the Coast Guard

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[65] *Global Ballast Water Treatment Systems Market* (Frost & Sullivan 2010).
[66] *Global Ballast Water Treatment Systems Market* (Frost & Sullivan 2010); Cleantech Group Analysis

implemented for vessels entering the Great Lakes and other US ports only required vessels to conduct ballast water exchange. As a result of organism discharge criteria not being included, system vendors were not motivated to develop ballast water treatment systems and ship owners were not compelled to purchase them. If stringent global regulations are passed and enforced, a strong market for ballast water treatment systems is anticipated; if regulation fails, the market will falter.

Overall, the sector is estimated to experience a 52.8% CAGR through 2020.[67] From 2013 – 2016, the global ballast water treatment systems market is expected to experience slow to moderate growth, with revenues coming predominantly from Asia Pacific, as newly built vessels install solutions. The subsequent period (2016 – 2018) should experience more rapid growth, with the majority of revenues expected from both Europe and Asia Pacific, as existing vessels are retrofitted and new vessels continue to be brought to market. Based on primary interviews and secondary research, North America is not forecasted to be a large revenue market for ballast water treatment systems due to a limited shipbuilding capacity and relatively small fleet when compared to Europe or Asia Pacific.

12.2 Policy and Regulation

In 2004, the International Maritime Organization ("IMO"), a specialized agency of the United Nations, adopted the International Convention for the Control and Management of Ship's Ballast Water and Sediments ("the Convention"). The agency's primary purpose is to develop and maintain a comprehensive regulatory framework for shipping. Currently, the IMO has 170 Member States and three Associate Members.[68]

According to the Convention, a vessel is defined as any ship or offshore structure designed to carry ballast water. As it currently stands, this Convention would apply to all new vessels built from 2012 onwards, while older vessels will be held to phase-in requirements, leading to a total ban on transfer of harmful organisms by 2016. As ratification has not yet occurred, it is widely

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[67] *Global Ballast Water Treatment Systems Market* (Frost & Sullivan 2010).
[68] http://www.imo.org/About/Membership/Pages/Default.aspx

expected that the IMO will revise the timelines set out in the Convention. Regardless of its age or size, all vessels will be required to comply with ballast water exchange standards per the regulations outlined below.

Regulation D1: Ballast Water Exchange Standard – This regulation governs the exchange of ballast water during ship operations, and requires pumping through three times the volume of the ballast water tank to achieve efficiency of 95% volumetric exchange.

Regulation D2: Ballast Water Performance Standard – This regulation governs the treatment of ballast water to ensure specific standards are met at discharge. The chart below outlines the ballast water quality regulations in the Convention.

Organism Category	Regulation
Plankton, >50 µm in minimum dimension	< 10 organisms / m^3
Plankton, 10-50 µm	< 10 organisms / ml
Toxicogenic Vibrio cholerae (O1 and O139)	< 1 cfu* / 100 ml
Escherichia coli	< 250 cfu* / 100 ml
Intestinal Enterococci	< 100 cfu* / 100 ml

** cfu = colony forming unit*

Regulation D4 – This regulation applies to ships participating in approved programs to test and evaluate ballast water treatment technologies. These vessels will have a 5 year leeway before having to comply with requirements set out in the Convention. However, each vessel will be required to maintain ballast water management records and monitor for residual oxidants if active substances are used by the experimental technology during the testing period.

In order to bring the Convention into force, it must be ratified by 30 countries representing >35% of world merchant shipping tonnage. To date, 32 countries have ratified: Albania, Antigua & Barbuda, Barbados, Brazil, Canada, Cook Islands, Croatia, Egypt, France, Iran, Kenya, Kiribati, Republic of Korea, Lebanon, Liberia, Malaysia, Maldives, Marshall Islands, Mexico, Mongolia, Montenegro, Netherlands, Nigeria, Norway, Palau, Saint Kitts & Nevis, Sierra Leone, South Africa, Spain, Sweden, Syrian Arab Republic and Tuvalu. However, these countries only represent about

27% of world tonnage[69], short of the 35% requirement. Based on primary interviews with key equipment vendors, Panama, the largest Flag Country in the world by tonnage, is largely believed to be the final ratifying state to satisfy tonnage requirement and enable the Convention's entry into force. The flag state has already joined the IMO GloBallast Partnerships Project as a lead partner country.[70]

Enforcement of the Convention is slated to occur 12 months after ratification, per the following timeline (compliance depends upon ship's age and water capacity), which was developed in anticipation of a 2011 ratification and 2012 implementation:

Application dates (subject to ratification of Convention)							MUST BE IN COMPLIANCE		
Date of Construction	Ballast Water Capacity (m3)	2009	2010	2011	2012	2013	2014	2015	2016
- Before January 1, 2009	1500<BW<5000						→	→	→
- Before January 1, 2009	BW<1500, 5000<BW								→
- After January 1, 2009	BW<5000	→	→	→	→	→	→	→	→
- After January 1, 2009 and before January 1, 2012	5000<BW								→
- After January 1, 2012	5000<BW			→	→	→	→	→	→

In the United States, the US Coast Guard ("USCG") has been tasked with establishing controls on ballast water discharges that occur in U.S. waters. The federal agency issued voluntary guidelines for vessels operating on waters off the US and additional practices for vessels that enter U.S. waters after operating on waters beyond the Exclusive Economic Zone of the US and Canada (latter guidelines were made mandatory for all vessels entering the Great Lakes and the Hudson River north of the George Washington Bridge). However, as vessel compliance was deemed to be inadequate, the voluntary program became mandatory. In July 2004, ballast water management requirements were listed in Title 33: Navigation and Navigable Waters (Subparts C and D), which includes ballast operation reporting and recordkeeping requirements. The title outlines ballast

[69] http://globallast.imo.org/index.asp?page=announcements.asp
[70] Tom Leander. "Start installing now." Lloyd's List. October 6, 2011. http://www.lloydslist.com/ll/sector/regulation/article381433.ece

water management best practices that vessels must choose from, but does not specify ballast water quality standards to which discharged ballast water will be held.

The USCG has proposed a two-phase standard for ballast water discharge. Phase I (numerical discharge standard) is in line with the 2004 IMO Convention, while Phase II is expected to be more stringent. Additional regulations may surface on a state-by-state level but a recent bill passed by the US House of Representatives prohibits states from enacting ballast water regulations that exceed federal standards.

12.3 Technologies

12.3.1 Products

A large majority of ballast water treatment technologies have been adapted from trusted land-based water treatment technologies, with the most prevalent systems those that combine mechanical separation/filtration with UV radiation or chemical disinfection. They can be categorized into three distinct categories: Mechanical Systems, Physical Disinfection, and Chemical Treatments. Mechanical systems include filtration, surface separation, coagulation/flocculation, and hydrocyclone. Physical disinfection methods include ozone, UV, heat, deoxygenation, and gas injection. Finally, chemical treatment methods include peracetic acid, hydrogen peroxide, menadione/Vitamin K, and chlorination. The initial mechanical separation/filtration removes larger organisms and increases the effectiveness of secondary treatments.

All technologies must be approved by the IMO. The IMO certification process consists of G8 (Type) and G9 (Basic/Final) approvals, which can take up to 2 years and cost anywhere from $350,000 - $500,000. Type Approval is required for all ballast water treatment systems, and involves land-based and shipboard testing of equipment by a flag state. Only technologies utilizing active substances need to obtain Basic Approval (laboratory or bench-scale testing of system for persistency, bioaccumulation and toxicity) and Final Approval (a technical review of the physical equipment by the Group of Experts on the Scientific Aspects of Marine Pollution ("GESAMP"), an advisory body established by the UN). GESAMP will make approval/denial recommendations to IMO's Marine Environment Protection Committee, who then makes G9 approval decisions.

As of August 2011, IMO had granted approvals to systems of the following suppliers:[71]

Suppliers with Type Approval	Suppliers with Basic Approval	Suppliers with Final Approval*
1. Alfa Laval	1. China Ocean Shipping (COSCO)	1. Hamann AG
2. Hamann AG	2. Aquaworx	2. Techcross
3. Techcross	3. Siemens Water Technologies	3. Mitsui Engineering & Shipbuilding
4. OceanSaver	4. DESMI Ocean Guard	4. RWO Marine Water Tech (Permascand)
5. NK	5. Kwang San	5. Alfa Laval
6. Panasia	6. AQUA Eng Co	6. NK
7. Hitachi Plant Technologies	7. Kuraray	7. Hitachi Plant Technologies
8. Qingdao Sunrui	8. ERMA FIRST	8. Resource Ballast Technologies
9. JFE Engineering	9. Envirotech	9. Panasia
10. Resource Ballast Technologies	10. Katayama Chemical	10. OceanSaver
11. N.E.I. Treatment Systems	11. GEA Westfalia Separator Group	11. JFE Engineering
12. Hyde Marine		12. Hamworthy Greenship
13. Optimarin		13. Ecochlor
14. China Ocean Shipping (COSCO)		14. Hyundai Heavy Industries
15. Brightsky Electronic		15. Qingdao Sunrui
16. MAHLE Industrial Filtration		16. 21st Century Shipbuilding
17. Severn Trent De Nora		17. Qingdao Headway Technology
18. RWO Marine Water Tech (Permascand)		18. Severn Trent De Nora
19. Qingdao Headway Technology		19. Samsung Heavy Industries
20. AQUA Engineering		

**all companies with Final approval also have Basic approval*

In collaboration with EPA, the USCG developed a protocol for verification of ballast water treatment systems. Systems with Type Approvals from foreign administrations will need to undergo a separate evaluation procedure to ensure they are substantively the same as the US testing procedures.[72] Independent registration by EPA may also be required for systems that utilize biocides under the Federal Insecticide, Fungicide, and Rodenticide Act.

12.3.2 Services

Ship Owners / Operators (customers/users in the ballast water market)

[71] IMO. http://www.imo.org/OurWork/Environment/BallastWaterManagement/Documents/table%20updated%20in%20August%202011.pdf

[72] http://www.uscg.mil/hq/cg5/cg522/cg5224/docs/White%20Paper%20-%20Ballast%20Water%20Discharge%20Standard%20v3B.pdf

There are more than 1,000 ship owners, with leaders evenly split between Asia (China, Korea, Japan) and Europe (Germany, Greece). The top two ship owner countries – Japan and Greece – control 31% of the world's fleet.[73]

Large ship owners will typically contract with multiple system vendors to ensure each ship's unique needs are met. When choosing a system, ship owners will look at: IMO Approvals, total lifetime cost (installation and maintenance), technology (system's impact on ballast tank and piping coatings, substrate corrosion rates), footprint (size), power consumption, and user friendliness (crew training considerations). Ship operators have no voice in choosing ballast water treatment systems.

Shipyards

There are over 1,000 shipyards globally for an estimated 68,000 vessels in the world, with an average of 1,000 new builds annually. In Asia, shipyards may maintain a "Maker's List," which is a list of preferred system vendors. System vendors must present detailed technical information (e.g., flow rates, operating pressures, instrumentation, insulation needs, power demands, weight, etc.) and interface with shipyards on an engineering basis to ensure understanding of system integration with ships. With the expected increase in demand once the Convention enters into force, there are market concerns around shipyard capacity to install ballast water treatment systems in accordance with IMO's compliance timeline.

Agents / Distributors

An Agent is typically used for introductions and access to ship owners, with the purchasing contract held between the ship owner and system vendor. In contrast, a Distributor will resell systems through a licensing agreement with the system vendor.

Currently, there are no large global players. However, there are more than 100 regionally-focused companies to accommodate clusters of ship owners in various countries and to develop

[73] *Global Ballast Water Treatment Systems Market* (Frost & Sullivan 2010).

long-term relationships. Companies in this sector include Allweiler, Marubeni, and Daiki Ataka. System vendors will typically partner with a global network of agents and distributors, and separately cooperate with ship resupply and maintenance organizations at various ports for a global network of service providers.

12.4 Vendor landscape

According to research, there are estimated 40-50 system vendors at various stages of development or commercialization around the world. System vendors include traditional marine equipment and systems providers, specialized water and wastewater treatment system suppliers, start-ups, shipbuilders and ship owners. With the exception of the Middle East and Africa, where there are only an estimated 2% of system vendors, systems vendors are fairly evenly distributed around the globe, with North and South America accounting for 31%, Asia Pacific for another 31%, and Europe for the remaining 37%.

While the presence of system vendors in North America is strong, particularly within the United States, vendors will likely target Europe and Asia given the large shipbuilding industry in those regions. Within the United States, vendors are not concentrated in any one state, and as such, no state can claim to be the leader in development of ballast water treatment solutions at this time. Global market opportunities exist most readily for those companies who develop agent partnerships with companies that have a global brand known throughout the marine industry. Additionally, it is crucial for a systems vendor to have a global service presence through regional service centers.

The ballast water treatment systems market is nascent, and equipment vendor market shares (based on number of systems contracted) fluctuate fairly readily. In addition, market shares are expected to alter significantly upon ratification of the Convention due to an influx of orders from ship owners and new market entrants. Of extreme importance in the ballast water market is developing and maintaining relationships within the marine industry, as this poses quite a large barrier to entry for new market entrants with no maritime experience or connections. Alfa Laval, a global supplier of products and solutions for heat transfer, separation and fluid handling, is estimated to lead the sector with nearly 30% of the market share. The company has partnered with Wallenius to incorporate patented advanced oxidation technologies in its solution, which also relies on filtration and UV, and is currently believed to lead the market with sizeable contracts from Maersk, Wallenius and E.R. Schiffahrt. Optimarin, a company wholly focused on providing ballast water treatment solutions, is also considered to be a market leader with 22% market share. The company has secured major slices of the Norwegian offshore BWT market, with clients like Gulf Offshore, K-Line, Siem Offshore, Farstad, Eidesvik, STX, REM and Grieg. Other major vendors include RWO Marine Water Technology, OceanSaver, N.E.I. Treatment Systems, HydeMarine, and Techchross.

Vendors can gain a competitive advantage in the marketplace by establishing relationships with shipyards and, ultimately, being placed on their "Maker's List," which is a list of preferred system vendors. Additionally, according to primary market research, vendors with small, scalable systems are more likely to be favored by ship owners due to the limited space for treatment systems on existing ships (as they were not originally designed and engineered to house this equipment).

12.5 Venture activity

The ballast water market is very new and has not yet garnered a lot of attention in the venture capital market. As such, most of the funding has so far been raised from angel investors that choose not to disclose transaction values. In 2011, we recorded $1.7 million in VC funding, up from $0.7 million in 2010. The chart below highlights all the investment activity we have tracked for this sector, with each transaction accompanied by the year the investment was made.

Company	Country	Description	Capital raise	Round
AquaMats Holdings	China	Developer of pollution control products for aquatic environments with additional applications in aquaculture and wastewater treatment.	$10,000,000 (2007)	Growth Equity
Echochlor	USA	Developer and manufacturer of proprietary ballast water treatment system.	$1,700,000 (2011) $681,543 (2010)	Growth Equity Growth Equity
N.E.I. Treatment Systems	USA	Developer of a ballast water treatment system that induces a hypoxic condition to kill aquatic organisms and prevent corrosion in ballast tanks of oceangoing ships.	Undisclosed (2011) Undisclosed (2009) Undisclosed (2004)	Series B Series A Seed
Optimarin	Norway	Developer of ballast water treatment systems based on solid separation (filter) and high doses of UV irradiation.	Undisclosed (2007) Undisclosed (unknown)	Follow-on Follow-on
EnSo	Norway	EnSo has developed a technology that uses electricity to neutralise unwanted marine organisms in ballast water.	Undisclosed (unknown)	Seed

Other companies have not been so fortunate in attracting VC funding. MARENCO, an Anaheim, CA-based company, developed a ballast water treatment system up to prototype phase, but has chosen not to be the manufacturer of the systems. System testing successfully resulted in 100% elimination of zooplankton and 99.99% elimination of hydroplankton, but the company was co-founded by a group of experienced naval officers that lack the business vision to carry out marketing and distribution activities. The Company is now seeking a strategic partner to license its technology to produce and market systems, develop a joint venture partnership, or to secure an outright acquisition of the IP portfolio.

12.6 Company Profiles

The ballast water market is still in very early stages of deployment and no specific treatment solution has emerged as the innovative market leader. As such, we have identified three equipment vendors in the North American region that offer unique ballast water treatment solutions. N.E.I. Treatment Systems and Ecochlor have both received IMO approval and Trojan Marinex expects approval by early 2012.

- N.E.I. Treatment Systems
- Ecochlor
- Trojan Marinex

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