The Water Technology Sector in the United States

Examining stakeholders, trends and opportunities in the American water technology sector

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Foreword

This report is the result of a study conducted at The Netherlands Office for Science and Technology (NOST) located at the Royal Netherlands Embassy in Washington, D.C. Because of the need at NOST for an overview of the water technology sector in the United States, this study was conducted in the period of March through August 2013 as part of my internship at NOST. Already in February 2013, the Dutch water technology sector was examined by using available literature (Netherlands Water Partnership Report) and interviewing several Dutch water professionals.

For this research of the water technology sector, the United States (US) is divided in two parts. The scope of this report is on the eastern part of the US, meaning all the states east of the horizontal line North Dakota – Texas. The water technology sector west of this figuratively line will be scouted another time.

Figure 1: Dividing the US in two research foci.

The research objectives of my research in the United States were:

- Examine important stakeholders and the structure of the water technology sector;
- Identify trends, innovative techniques and scientific researches;
- Examine and identify water technology clusters in the United States;
- Compare the Dutch and American water technology sector.

My period in Washington D.C. was very inspiring. For me to experience the capital of the world was quite special. Moreover, researching an innovative, growing water industry is very stimulating, especially if you can contribute by creating awareness for the opportunities in the United States in the field of water technology.

I want to thank everyone who helped me to set up and complete this report with an overview of the water technology sector in the eastern part of the United States.

Sincerely,

Matthias Bosma

Summary

The water industry in the United States (US) is growing rapidly, offering opportunities in different sectors like equipment and oil and gas. The Safe Drinking Water Act and the Clean Water Acts are the most important federal policy programs within the American water technology sector. These programs, coordinated by the Environmental Protection Agency (EPA), provide treatment and discharge regulations, funding programs and frameworks for operating and applying innovative water and wastewater treatment technologies. Other federal agencies are involved in financial programs as well.

The techno-economic network analysis that has been made of the American water technology market is starting to be more convergent, meaning that communication between the different actors is increasing. Specific questions or problems are addressed by efforts of actors working together in the network, for example participating in public private partnerships. Because the different actors in the US water technology sector are collaborating and communicating more, the techno-economic network is a strong network.

Within the US water technology sector several trends have been identified that offer potential technological opportunities.

- The <u>aging drinking water and wastewater infrastructure</u> is in poor condition and systems require investments in maintenance, repairs and upgrades. Also new and more cost effective assessments (e.g., leak detection, prediction models of condition systems, asset management models) and rehabilitation techniques are needed. Green infrastructure for storm water management and decentralized approaches that can reduce pumping and treatments costs are receiving more attention.
- <u>Water reuse</u> and the use of <u>reclaimed water</u> are widely applied and is increasing in the US. Industrial water reuse continues to gather momentum and onsite water reuse is becoming one of the most adaptable approaches by industries. There are significant needs for technologies and approaches that foster substantially greater water reuse, or sewer mining, which in turn can reduce pollution and conserve energy.
- Although the US is the <u>second largest desalination market</u> in the world after Saudi Arabia, desalination is not widely used at a large scale in the US. However, desalination is gaining more attraction, particularly in the arid coastal regions where production of water and disposal of waste is more feasible. Challenges include brine disposal, pretreatment optimization, energy conservation and overall productivity of membrane systems.
- An important issue in the American water technology sector is <u>storm water management</u>. Stricter federal and state regulations for wastewater and storm water systems are the main drivers for improving such systems. There is a need for technologies that address non-point sources of pollution. There is a demand for storm water control mechanisms and green infrastructure (e.g., recharge basins, rapid infiltration beds, bioretention systems).
- <u>Nutrient recovery</u> (e.g., wastewater mining) will be an important topic in the United States for the coming years. Driven by the need to reduce nutrient pollution (e.g., more stringent regulations) in surface water and drinking water supplies (caused by e.g., nitrogen and phosphorous), emerging technologies for treating and recovering nutrients in a more efficient way from water and wastewater will be needed in the United States.
- In the US many utilities are considering changes in treatment process to avoid noncompliance with new disinfection byproduct (DBP) rules. The stage II of DBP regulations therefore is an important driver for technological changes in <u>disinfection methods</u>. As a result advanced

oxidation, ozonation, electro chlorination, biological filtration and other disinfection methods are becoming increasingly popular in the US.
- Smart water networks are growing in the US. Smart water grid techniques (e.g., smart water meters, electromagnetic and acoustic sensors, basic data management software, real-time data analytics and modeling software) are needed in order to address non-revenue water, to increase energy efficiency and reduce costs.
- Monitoring and removal of emerging contaminants (e.g., pharmaceuticals, nanomaterial) will be a trending topic in the US water technology market in the coming years. These contaminants of emerging concern (CECs) are often unregulated and occur in untreated and fully treated water and wastewater. The EPA will be implementing new or stricter drinking water limits on numerous contaminants. Therefore, techniques to monitor and remove those emerging contaminants are needed.

Within the US water technology sector several water clusters and initiatives have been identified that offer potential opportunities for collaboration to commercialize products for the American market. The water technology clusters and initiatives are established to become international water hubs, developing and commercializing new and innovative technologies, and attracting business and universities (e.g., Confluence, Milwaukee, Michigan, Northeast Ohio, and Massachusetts). The clusters and initiatives are looking for international collaboration. For example, The Akron Water Initiative is looking for partnerships with foreign parties, especially Dutch water technology companies and startups. Some water clusters and initiatives offer programs to support companies, with facilities like pilot test sites, accelerators, professional teams, aid by finding funding, validating technologies (e.g., Milwaukee Global Water Center, Indianapolis: Living laboratory for smart water grid technologies, The City of Akron's Accelerator, Massachusetts). Storm water management is also a major issue for most clusters and initiatives (e.g., Northeast Ohio (Cleveland and Akron), Michigan, The Greater Pittsburgh region, Philadelphia).
Other challenges in the different regions are:

- Water-related problems caused by hydraulic fracturing (brine disposal in e.g., NE Ohio, Pennsylvania)
- Water quality challenges caused by non-point sources (nutrients, toxic algae in e.g., Michigan, Philadelphia, Chesapeake Bay area)
- Aging water infrastructure and the renewal of it (water accessibility and quality in e.g., Indianapolis. Ohio, The Greater Pittsburgh)
- Flood resistance of water and wastewater infrastructure (e.g., Florida, New York City).

Both the American and the Dutch water sector have a lot in common regarding water issues and research themes. Innovative water technologies and equipment are needed in order to find solutions for water issues in the United States. The Dutch water technology sector offers specific niche water technologies that form potential solutions for the US water issues. The American water clusters and initiatives have opportunities to support Dutch companies to enter the US market.

Dutch Summary

De watertechnologie markt in de Verenigde Staten (VS) groeit snel en biedt daardoor kansen in verschillende sectoren. De Safe Drinking Water Act en de Clean Water Act vormen binnen de Amerikaanse watertechnologie sector de belangrijkste federale beleidsprogramma's. Deze programma's, die door de Environmental Protection Agency (EPA) gecoördineerd worden, voorzien in zuiverings- en lozingseisen, financieringsprogramma's en kaders voor het beheren en toepassen van innovatieve water- en afvalwater technologieën. Andere federale overheden zijn via eigen financierings- en subsidieprogramma's ook betrokken bij de watersector in de Verenigde Staten.

De techno-economische netwerk analyse dat van de Amerikaanse watertechnologie sector is gemaakt, laat zien dat het netwerk steeds samenhangende wordt. Dit betekent dat de communicatie tussen de verschillende actoren in de watertechnologie toeneemt. Specifieke vragen en problemen worden opgelost doordat de actoren in het netwerk vaker moeite doen om samen te werken via bijvoorbeeld publiek private samenwerkingen. Doordat de verschillende actoren in de Amerikaanse watertechnologie sector samenwerken en communiceren is het techno-economisch netwerk een sterk netwerk.

Binnen de watertechnologie sector in de Verenigde Staten zijn verscheidene trends geïdentificeerd die potentiele technologische kansen bieden.

- De <u>verouderde drinkwater en afvalwater infrastructuur</u> in de VS is in slechte staat en veel infrastructuur heeft investeringen nodig op het gebied van onderhoud, reparaties en vernieuwing. Daarnaast is er behoefte aan nieuwe en kosten effectieve assessments (e.g., lek detectie, prediction models of condition systems, asset management models) en rehabilitatie technieken nodig. De aandacht voor groene infrastructuur voor het beheersen van overtollig regenwater en decentrale concepten om de pomp en vervoerskosten te beperken is aan het toenemen.
- <u>Waterhergebruik</u> en het <u>gebruik van teruggewonnen water</u> worden op grote schaal toegepast en het gebruik neemt steeds toe. Vooral waterhergebruik in de industrie neemt snel toe en on-site waterhergebruik is één van de meest toegepaste methodes van hergebruik aan het worden. Er is behoefte aan technologieën en methoden die waterhergebruik bevorderen om vervuiling te verminderen en energiebesparing op te leveren.
- Hoewel de VS, na Saoedi Arabië, de een na grootste <u>ontziltingsmarkt</u> in de wereld is, wordt ontzilting nog niet op hele grote schaal toegepast in de VS. Men verwacht een toename in toepassingen van ontzilting van zeewater en brak water, vooral in de drogere kustgebieden in de VS waar productie en afvoer van het water makkelijker zijn. Uitdagingen binnen deze markt liggen op het gebied van de behandeling en afvoer van het concentraat, voorbehandelingsoptimalisatie, energiebesparing en de overall productiviteit van de membraansystemen.
- <u>Regenwater management</u> is een zeer belangrijk en actueel probleem in the Amerikaanse watertechnologie sector. Gecombineerde afvalwater en regenwater systemen moeten verbeterd worden als gevolg van striktere wet- en regelgeving op federaal en staat niveau. Er is behoefte aan technologieën die een oplossing bieden voor de problemen met diffuse vervuilingsbronnen. Ook is er vraag naar mechanismen om regenwater te controleren en groene infrastructuur (e.g., recharge bassins, rapid infiltration beds, bioretention systems).
- In de komende jaren zal de <u>terugwinning van nutriënten</u> (e.g. wastewater mining) een belangrijk onderwerp worden in de watertechnologie sector in de VS. Door striktere wet- en regelgeving moet de vervuiling door nutriënten (e.g., stikstof en fosfaten) in oppervlaktewater en drinkwater voorraden verminderd worden. Opkomende innovatieve technologieën zullen nodig zijn zodat

nutriënten op efficiëntere manier verwijderd en teruggewonnen kunnen worden uit drink- en afvalwater.
- In de VS zijn veel drink- en afvalwaterbedrijven aan het nadenken over het aanbrengen van veranderingen in hun zuiveringsprocessen om op die manier te kunnen voldoen aan nieuwe desinfectie bijproduct regels. Fase II van de desinfectie bijproduct regels is daarom een belangrijke driver voor technologische veranderingen in desinfectiemethoden. Een gevolg hiervan is dat advanced oxidation, ozonation, electro chlorination, biological filtration, en andere disinfectie methoden steeds populairder worden in de VS.
- Slimme water netwerken worden steeds vaker toegepast in de VS. Smart water grid technieken (e.g., smart water meters, elektromagnetische en akoestische sensors, basic data management software, real-time data analytics en modeling software) zijn nodig om de uitdagingen met non-revenu water op te lossen, de energie efficiency te vergroten en de kosten te verlagen.
- In de komende jaren zal de monitoring en verwijdering van nieuwe verontreinigende stoffen (e.g., pharmaceuticals, nanomaterials) een trending topic worden in de Amerikaanse watertechnologie sector. Deze Contaminants of Emerging Concern (CECs) zijn vaak ongereguleerd en komen voor in ongezuiverd en volledig gezuiverd drinkwater en afvalwater. De EPA is bezig met het implementeren van nieuwe en striktere drinkwater eisen voor verschillende verontreinigingen. Daarom zal er behoefte zijn aan technologieën die zulke opkomende verontreinigde stoffen kunnen registreren en verwijderen.

Binnen de watertechnologie sector in de VS zijn verscheidene waterclusters en initiatieven gevonden die potentiele kansen bieden voor samenwerking om producten te commercialiseren voor de Amerikaanse water markt. Deze watertechnologie clusters en initiatieven zijn opgericht met het doel om internationale water hubs te vormen, om nieuwe en innovatieve water technologieën te ontwikkelen en te commercialiseren, en om bedrijven en universiteiten voor samenwerking aan te trekken (oa Confluence, Northeast Ohio). De meeste water clusters en initiatieven staan open voor internationale samenwerking. Het Akron Water Initiative is geïnteresseerd in samenwerkingen met buitenlandse partijen, in het bijzonder met Nederlandse watertechnologie bedrijven. Sommige water clusters en initiatieven in de Verenigde Staten bieden programma’s aan die bedrijven ondersteunen door middel van pilot test plekken, professionele begeleidingsteams, vinden van financiering of hulp bij het valideren van technieken (oa Indianapolis Living Laboratory for smart water grid technologies, The City of Akron’s Accelerator). Regenwater management is een belangrijk thema voor de water clusters en initiatieven (oa Northeast Ohio (Cleveland en Akron), Michigan, The Greater Pittsburgh region, Philadelphia). Andere grote uitdagingen in de verschillende regio’s zijn:

- Water gerelateerde problemen veroorzaakt door hydraulic fracturing (brine disposal in oa NE Ohio, Pennsylvania)
- Waterkwaliteit uitdagingen veroorzaakt door diffuse bronnen (nutriënten, toxische algen in oa Michigan, Philadelphia, Chesapeake Bay area)
- Verouderde water infrastructuur en de vernieuwing daarvan (water toegankelijkheid en kwaliteit oa in Indianapolis. Ohio, The Greater Pittsburgh)
- Bescherming van drinkwater en afvalwater infrastructuur tegen overstromingen (oa in Florida, New York City).

De Amerikaanse en de Nederlandse watertechnologie sector hebben qua water trends en onderzoeksonderwerpen veel overeenkomsten. De Verenigde Staten heeft behoefte aan nieuwe en innovatieve technologieën en apparatuur om de uitdagingen aan te kunnen. De Nederlandse watertechnologiesector biedt hoogwaardige technieken aan in niche markten die potentiele oplossingen kunnen bieden voor de water kwesties in de VS. Sommige Amerikaanse water clusters en initiatieven bieden hulp aan bij het betreden van de markt.

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1. Introduction

Globally, the water technology market is growing, creating new opportunities for companies, universities and other organizations to commercialize their products, start collaborations for knowledge and technology transfers and to solve water availability problems in the world. Besides emerging countries like China and Brazil, the United States also offers opportunities in the field of water technology. This chapter will provide an introduction to the American water technology market by describing some key facts of the market, the federal water policy and ways of financing water-related projects.

1.1 Key facts

The US water market is the largest water-related goods and services market in the world and is growing rapidly. In 2010, the total US water market was estimated to be $107 billion, growing with an annual rate of 10-14.9%. Within this market, the industrial market was estimated to be $5.7 billion and the utility market $80.7 billion. The following economic water trends and predictions are taken from the Global Water Market 2011 report.[1] However, the latest version (Global Water Market 2014) was not yet available at the time of my internship.

- The total utility water and wastewater capital expenditure in the US will grow from $26.8 billion in 2010 to $49.8 billion in 2016. The largest area of expenditure is the rehabilitation of the water and wastewater distribution network (39.2%), followed by capital expenditures for upgrading water and wastewater treatment plants (34.9%). Seawater and brackish water desalination (for drinking water production) expenditures will be the fastest growing market within the utility market, from $256 million in 2010 to $1.9 billion in 2016.

- The total industrial water capital expenditure in the US will increase from $2.5 billion in 2010 to $3.9 billion in 2016. Especially the water capital expenditures in the oil and gas sector will grow dramatically, from $100.5 million in 2010 to $509.7 million in 2016. Other industrial water sectors that will grow significantly between 2010 and 2016 in the US are power generation (+52%) and food, beverage (+32%) and pharmaceutical manufacturing (+39%).

- The total industrial and municipal equipment market in the US is forecast to grow from $16.9 billion in 2010 to $30.2 billion in 2016. The fastest growing water technology markets in the US between 2008 and 2016 will be ultrafiltration and microfiltration membranes (+280%), UV disinfection (+227%), ozone disinfection systems (+233%), membrane bioreactors (+180%), and reverse osmosis membrane systems (+165%).[2] The demand for water treatment equipment will grow to $13 billion in 2017.[3]

1.2 Federal water policy

The US Environmental Protection Agency (EPA) and state environmental agencies, directed by EPA's 10 regional offices[4], regulate the drinking and wastewater supplies in the water and wastewater cycle as shown in figure 2. The two underlying laws that govern the water technology sector are the Safe Drinking Water Act (SDWA) of 1974 and the Clean Water Act (CWA) of 1972.

[1] Global Water Intelligence, 2010
[2] Water Market USA, 2008, http://www.wwdmag.com/water-market-report-predicts-long-term-growth
[3] http://www.freedoniagroup.com/industry-study/3052/water-treatment-equipment.htm
[4] http://www2.epa.gov/aboutepa/#pane-4

In the past, local governments and states were responsible for their own water supply and wastewater treatment. Most states and local authorities in those days only used primary treatment (e.g., primary sedimentation tanks). Surface water quality deteriorated quickly, with potential consequences for drinking water supply and the environment. In order to create funding and financing for improvements, both above mentioned acts were established.

The use of water is considered as an important right in the United States. The allocation of water is determined by two different principles: prior appropriation and riparian water rights.
The riparian water rights are mostly applied in the eastern states of the US and include that property owners adjacent to water bodies (e.g., rivers, lakes, stream) in a watershed, have the right to use this water reasonably, for swimming, fishing, sailing and other useful purposes (e.g., irrigation, livestock watering, pollution control). Riparian water rights cannot be sold or transferred separately from the property. These rights also do not allow transportation of water from one to another watershed.
The appropriation water rights are often applied in the western states of the US and are based on the "First in time, first in right" principle. This means that the first person, who is using a certain amount of water from a body of water, acquires the right to use this amount continuously over time. Other users of water are only allowed to exploit the remaining amount of water. Appropriation water rights are not bound to the property. Therefore, it is allowed to transfer water for useful purposes to other watersheds. This can lead to imbalances in water allocation between different watersheds.[5]

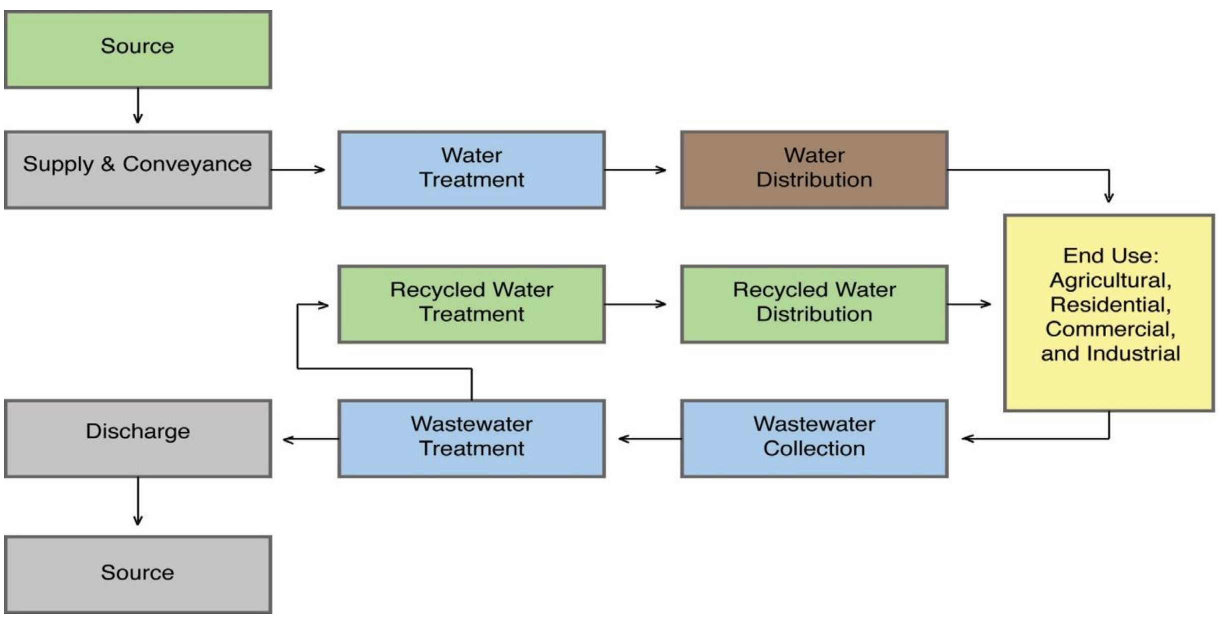

Figure 2: The water and wastewater cycle.[6]

1.2.1 Clean Water Act

The goal of the Clean Water Act (CWA) is to protect the water quality of American surface waters (e.g., rivers, lakes, coastal waters) and to maintain and restore the physical, chemical and biological values. The CWA made secondary treatment mandatory for all public wastewater treatment systems. Also, this law made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit is obtained.

[5] http://www.waterboards.ca.gov/waterrights/board_info/water_rights_process.shtml
[6] Presentation, Lorraine White, GEI Consultants, June 19, 2012, slide 5.

According to the results of interviews conducted, the most important CWA permit program is the National Pollutant Discharge Elimination System (NPDES) permit program, which regulates direct and indirect discharges of point sources (e.g., industrial and commercial facilities). For direct wastewater discharges to surface waters by industrial and commercial facilities, the general NPDES permit applies: permitting on-site sewage treatment technologies. For indirect wastewater discharges, the NPDES pretreatment program applies: which permits wastewater discharges to municipal sewer systems or publicly owned treatment works (POTWs), controlling interference and pass-through of pollutants.[7]

The American states have the authority to promulgate and administer such permits. For five states (Massachusetts, New Hampshire, Alaska, Idaho and New Mexico) NPDES permits are regulated via the EPA's regional offices. The discharge limits in NPDES permits are determined based on a combination of water quality standards and technology-based limits, whereby the most stringent limit applies.

The water quality standards are determined by the ecological water quality standards of the receiving type of surface water. The EPA has defined seven main types of water bodies (e.g., lakes and reservoirs, rivers and streams, oceans, coasts, estuaries and beaches) and is responsible for determining intended uses of these water bodies (e.g., swimming, fishing, drinking water source). It recommends water quality criteria and standards for specific pollutants per type of water body to the state environmental agencies. This advice serves as a framework and is not intended as a minimal requirement that has to be implemented before a certain deadline. The state and local authorities are not obligated to adopt or implement the recommendations of the EPA. They determine their own water quality criteria and standards for specific contaminating substances to protect human health and aquatic life in ambient water, which may be more or less stringent.

The technology-based limits are national standards, which are developed and established by the EPA. These standards intend to realize the greatest possible reduction of pollutants with techniques that are economical feasible for the industry. Therefore, the EPA identifies best available technologies (BATs) for different industrial categories. Based on the treatment process' performance and efficiencies, regulatory effluent limits are determined by EPA with which the technology (e.g., end of pipe treatment technology) has to be able to comply with. These national standards serve as a minimal requirement that apply for all the states.[8]

The effluent limits for indirect industrial and commercial discharges to POTWS are determined after analysis of the national pretreatment standards and local limits. The permit is administered by local authorities or entities (e.g. city's wastewater division or utility).[9]

Discharges of storm water from industrial and commercial facilities are considered as point sources and require coverage under an NPDES permit. Therefore, storm water runoff is covered under the storm water NPDES permitting program. Regulations and policies related to storm water are determined at the state and local level. Permitting is also authorized to states.[10]

Wastewater treatment systems are generally in compliance with federal requirements for effluent discharges, although most urban utilities face increasing storm water and municipal sewer overflow challenges.

[7] http://cfpub.epa.gov/npdes/index.cfm
[8] Presentation ,Jan Matuszko, USEPA Office of Water, *Clean Water Authorities and Activities Applicable to Oil and Gas Extraction*, May 2013
[9] http://cfpub.epa.gov/npdes/home.cfm?program_id=3
[10] http://cfpub.epa.gov/npdes/home.cfm?program_id=6

1.2.2 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) was established in order to set up national, enforceable drinking water standards for public water systems and the necessary monitoring systems. EPA regulates the approximately 155,000 public water systems in the US. Public water systems can be described as a system for providing water to the public for human consumption through pipes. They are defined as having 15 service connections or regularly serving at least 25 persons for at least 60 days a year. Most of the public water systems are small or very small, which makes it difficult to regulate and maintain the national drinking water standards that are established by the EPA.[11]

The National Primary Drinking Water Regulations (NPDWR) establishes standards based on maximum contaminant levels (MCLs) or treatment technique requirements for drinking water contaminants. The last update was The Safe Drinking Water Act Amendments of 1996 that included significant changes (e.g., stricter standards) to national drinking water standards. Currently, the regulated drinking water contaminants include MCLs for inorganic- (e.g., nitrate, arsenic), volatile organic- (e.g., benzene), synthetic (e.g., pesticides), radiological- (e.g., radium) & microbial contaminants, disinfection byproducts and residuals (e.g., bromoform), lead and copper.

The states are obligated to implement the NPDWRs in their drinking water supply system and they are allowed to implement stricter water regulations. Primary enforcement of the SDWA is delegated to the states.

All public water systems in the states are required to monitor the water in order to demonstrate that the water supply complies with MCLs or treatment requirements. Monitoring requirements vary with system type, size and source type (e.g., groundwater or surface water) and monitoring may be required for treated water, distribution systems or at the source. The EPA identifies three types of public water systems:

- Community;
- Non-transient non-community (e.g., schools, hospitals);
- Transient non-community water systems (e.g., campgrounds).[12]

Water utilities (public and private) are in the process of meeting stricter limits set by the EPA on drinking water contaminants, in particular arsenic, radioactive particles, microbial and disinfection by-products.

The SDWA requires EPA to protect underground sources of drinking water from contamination caused by underground injection. The EPA Underground Injection Control (UIC) program regulates the injection of waste and water into underground wells or depleted reservoirs. Within in this program six classes of wells are identified. About 800,000 injection wells are used in the US, ranging from brine disposal related to oil and gas production (Class II), to fresh treated water storage in order to use it later in a drought period or for replenishing aquifers to be protected against salt intrusion (Class V).[13]

1.3 Financing

The two largest sources of federal funding for water and wastewater infrastructure in states and local communities are the Clean Water and Safe Drinking Water State Revolving Fund (SRF). Both funds are

[11] Presentation Michael Finn, USEPA Office of Ground Water and Drinking Water, *Drinking water Regulation and Monitoring, May 2013*

[12] http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm

[13] Presentation Bruce Kobelski, Office of Water Drinking Water Protection Division, EPA Office of Ground Water and Drinking Water: Activities Related to Class II Injections Wells, May 2013

administered by the EPA and started in respectively 1987 and 1997. These funds are intended to assist states and local communities to implement the CWA and SDWA requirements.

The EPA and its Office of Water receives federal appropriations from Congress. Through the Clean Water and Safe Drinking Water SRF these federal appropriations are granted to the states. In the fiscal year 2012, the EPA financed $1.5 billion for the Clean Water SRF and $918 million for the Safe Drinking Water SRF.

The states use this money in combination with state funds, in order to loan low- or no-interest money to local communities, municipalities and utilities. The local communities and utilities use this capital for investments in renewing, replacing, improving distribution systems, drinking water and wastewater treatments systems, sewer lines and other similar water technology infrastructure. Repayments of the loaned capital refill the SRFs.

Funding from the Clean Water SRF can be used for renewing, replacing or updating secondary or advanced wastewater treatment facilities. It is also possible to spend this money for improving the collection system (e.g., sewer lines). The CWSRF program funds a significant amount of nonpoint source and estuary activities such as watershed management, wetlands protection, contaminated urban and rural runoff control, ground water protection, habitat protection, and estuary management.[14]

Safe Drinking Water SRF funds can be used to replace or to update water infrastructure that causes incompliance with the drinking water standards, like aging water conservation tanks, distribution pipeline or drinking water treatment plants. With the help of the Drinking Water SRF both private and public community drinking water systems, as well as nonprofit noncommunity systems can be supported financially. In contrast with the Clean Water SRF, every state in the United States is required to receive 1% or more of the Safe Drinking Water SRF.[15]

Both programs are chronically underfunded in comparison with the needs in the water and wastewater infrastructure. Presently, water and wastewater treatment plants are aging and in need of replacements and improvements, whereby the latest technologies have to be applied in order to comply with modern standards for water quality (see paragraph 3.1).

The federal stimulus bill of 2009 provided a short-term increase in funding, because The American Reinvestment and Recovery Act (ARRA) provided extra appropriations for the Clean Water SRF ($4 billion) and Drinking Water SRF ($2 billion).[16]

As described earlier several federal departments are involved in the American water technology sector. Table 1 contains an overview of the most important programs that provide financial assistance to states and local communities for investing in water and wastewater infrastructure.

Another source for funding and financing water technology projects is the private sector. According to my interviews, the six largest private companies invest each year about $2 billion in the American water infrastructure.

[14] http://water.epa.gov/grants_funding/cwsrf/cwsrf_index.cfm
[15] http://water.epa.gov/grants_funding/dwsrf/index.cfm
[16] http://water.epa.gov/grants_funding/eparecovery/

Table 1: The financial programs of US federal agencies.[17]

Agency, Program	Financial assistance provided
EPA, Clean Water State Revolving Fund	Grants to fund states. States provide loans to communities of all sizes for wastewater treatment infrastructure, nonpoint pollution management, and estuary programs.
EPA, Drinking Water State Revolving Fund	Grants to fund states. States provide loans to communities of all sizes for drinking water infrastructure.
Department of Agriculture, Rural Utilities Service, Water and Waste Disposal Program	Provides funding for water and wastewater infrastructure projects in communities with populations less than 10,000 people.
Department of Housing and Urban Development, Community Development Block Grant	Provides block grant funds to states for distribution to communities, and to certain metropolitan areas; communities use funds for a broad range of activities including water and wastewater infrastructure. According to department officials, about 10 percent of funding is used for this purpose.
Department of Commerce, Economic Development Administration, Public Works and Economic Development Program	Provides grants to small and disadvantaged communities to construct public facilities, including drinking water and wastewater facilities, to alleviate unemployment.
US Army Corps of Engineers	Provides assistance for water and wastewater infrastructure projects, typically for specific locations as authorized by Congress.
Bureau of Reclamation	Provides assistance for water supply projects through individual projects and under its rural water supply program.
Indian Health Service	Provides funding for water and wastewater infrastructure on tribal lands.
Department of the Treasury, Internal Revenue Service	Administers provisions for tax-exempt bonds issued by local governments to finance qualified projects.

Financing water projects through public private partnerships with municipalities is becoming more common in the American water technology sector. Although forming public private partnerships is still difficult for municipalities (e.g., complicated structure, negotiations and overview), water projects can be financed in this way with public and private capital. The Netherlands and Canada are fine examples in this regard. In Canada, federal and provincial governments support municipalities by delivering advice and professional services. As a result, public private partnerships in Canada have increased in recent years, both in volume and in capital that has been transferred via transactions. In The Netherlands it is obligatory to finance water projects through public private partnerships in order to receive approval. With the top sector policy, governmental funding will only be received if public private partnerships are used to finance water technology projects. In this way it is stimulated to form such partnerships. The Dutch water technology sector has a lot of experience with public private partnerships.

One factor affecting the need for funding is the low tariff (water rate) in the United States. Clean, cheap water has been considered a right by many in the US, resulting in water rates of less than a penny per gallon drinking water (or 0,2 Euro cents per liter). However, after a decade of outpacing other utility rate increases, water prices are receiving increased scrutiny from both consumers and state regulators.

[17] US Government Accountability Office, *Water Infrastructure, Approaches and Issues for Financing Drinking Water and Wastewater Infrastructure*, page 3, http://www.gao.gov/assets/660/652976.pdf

Since the price of delivering drinking water is largely driven by the capital costs of maintaining an aging infrastructure, water bills have been rising and are expected to continue rising in the future. At the same time, utilities are facing higher costs to treat and deliver water, with stricter EPA regulations and increasing energy prices. For instance, the average monthly residential water and sewer bill in Washington D.C. has increased by $36 in the last five years to an average of $78 per month (for using 5,004 gallons).[18] Such significant increases in water rates are already causing concerns in many parts of the country. As a result, regulatory agencies are expected to push utilities to improve efficiency and reduce the amount of nonrevenue water, lost through leaks and water main breaks, with better asset management (see paragraph 3.1).

This chapter provided an introduction into the water technology market in the United States. The water industry in the US is growing rapidly, offering opportunities in different sectors (e.g., equipment, (industrial) wastewater treatment). The Safe Drinking Water Act and the Clean Water Acts are the most important federal policy programs coordinated by the EPA. They provide treatment and discharge regulations, funding programs and a framework for operating and applying innovative water and wastewater treatment technologies. Other federal agencies are involved in financial programs as well.

[18] Presentation George Hawkins, General Manager DC Water, Water Innovation Alliance Foundations Water 2.0 Event, May 2013 (see http://www.dcwater.com/customercare/rates.cfm)

2. Structure and stakeholder analysis

The goal of this chapter is to create insight in the comprehensive structure of the sector, focusing on the type of relationships between the different stakeholders or actors in the American water technology sector. In order to examine the type of relations, roles and interactions a techno-economic network analysis has been made. This chapter will describe the results of this analysis and provide an overview of the structure and important stakeholders in the water technology sector in the United States.

2.1 Techno-economic network

The techno-economic network analysis has been performed based on an article written by Callon.[19] The techno-economic network analysis shows the relation and interaction between actors and their roles in the network. In this case the network is the American water technology sector. Three main groups can be identified in the network, namely Technical (policy), Scientific and Market. Other organizations and actors are surrounding these main groups in different relations (e.g., S → M). The techno-economic network for the American water technology sector is shown in figure 3.

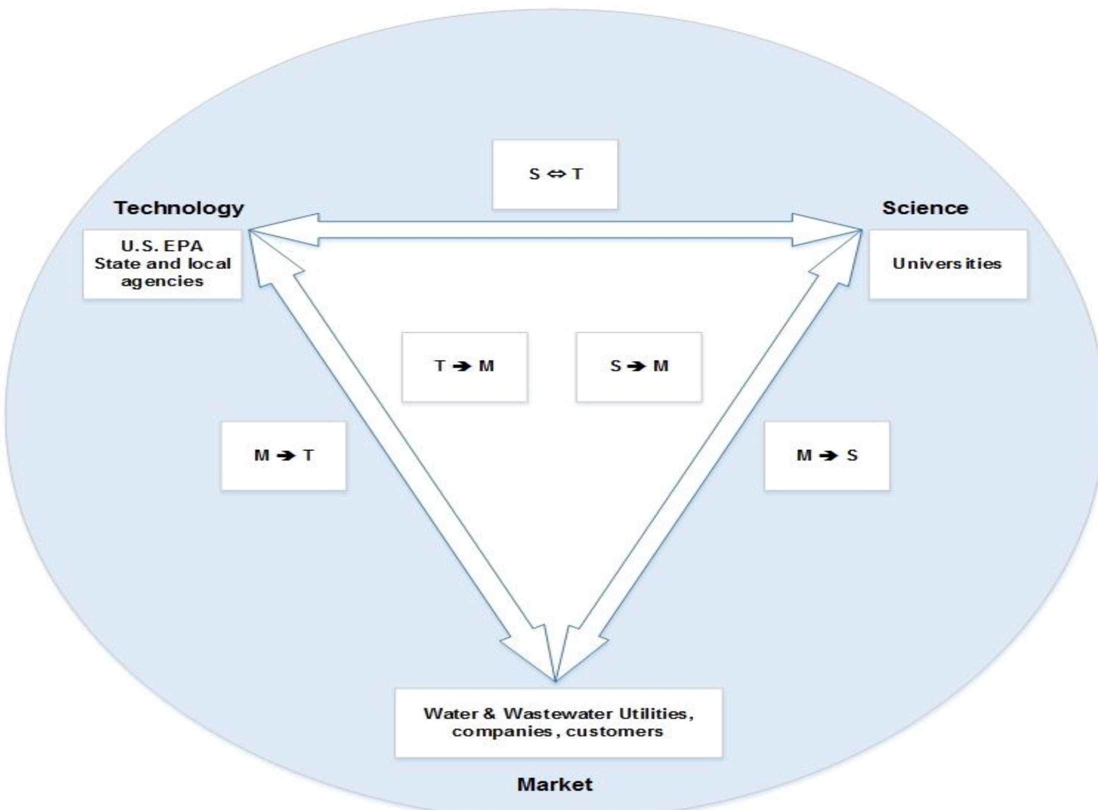

Figure 3: Techno-economic network for the US water technology sector, according to Callon.[20]

[19] Callon et al. (1992).
[20] Callon et al. (1992).

In the case of the water technology sector in the United States, the Science main group (S) represents those actors that develop knowledge about water technologies (e.g., wastewater treatment techniques) and water issues (e.g., behavior and effects of contaminants). The focus of this group is on new innovative scientific and applied research. Universities and research institutes belong to this group.

The role of the Technology main group (T) is to establish water policy (e.g., discharge limits) on a federal, state and local level (e.g., municipalities and cities) in order to maintain, develop and protect the water quality of water sources in the United States. The Technology group is also responsible for establishing and enforcing regulations and runs different programs to stimulate water and wastewater infrastructure projects and research, financed by grants and loans. Organizations that are included in this group are the US Environmental Protection Agency (EPA) and environmental state agencies.

The Market main group's (M) function is to implement water policy (e.g., federal and state) and regulations and use the information from research so that water and wastewater treatment systems are in compliance with the latest requirements for safety, technology practices and operations, effluent discharge limits and others. The Market group includes public and private local water and wastewater utilities, companies (e.g., contractors, equipment suppliers, engineering and consultancy firms) and the customers or end-users.

The two-way relation between Science and Technology policy (S ⇔ T) includes actors that translate and implement scientific knowledge into water-related policy themes and regulations. They also set out research projects to gain information that is needed from a policy perspective. In the American water technology sector, the EPA Office of Research and Development fulfill this task by having several federal water-related research programs. The US Army Corps of Engineers (USACE) Institute for Water Resources (IWR) is conducting research (e.g., analysis of emerging water resources trends and issues) to aid their Civil Works program.

The Market to Science (M ➔ S) relation includes actors that provide research from a market perspective, driven by Market needs and demands. Scientific and applied research is conducted by organizations like the WateReuse Research Foundation and the Water Environment Research Foundation.

The Science to Market (S ➔ M) relation includes actors that translate scientific results to market themes. They are informing the Market group about the latest scientific insights, tools, issues and developments in the field of water technology (e.g., drinking water, wastewater, storm water, reuse, desalination), by education and communication. This group includes the American Water Works Association and the Water Environment Federation and the WateReuse Association.

The Technology to Market (T ➔ M) group advocates for the interests of actors from the Technology group towards the Market. In the case of the water technology sector in the United States, this responsibility includes overseeing and monitoring grants programs and enforcing of policy regulations. The EPA's Office of Water and the state environmental agencies do this.

The Market to Technology (M ➔ T) group advocates for the interests of Market actors towards the Technology group. Organizations like, the National Association for Water Companies, the National Association for Clean Water Agencies, the Water and Wastewater Equipment Manufacturers Association and the National Rural Water Association are the examples of spokesmen of several Market actors. Also organizations like the US Water Alliance, Alliance for Water Efficiency and Water Innovations Alliance are advocating for polices, standards and programs in the field of water technology.

Techno-economic networks have certain properties. A network can be chained or incomplete, convergent or dispersed and long or short. In case of the US water technology sector, the techno-economic is chained, meaning that all different groups of actors in the network are represented. In the ideal situation, every group within the network would have an equal amount of actors. In this techno-economic network analysis the S ⇔ T actors are underrepresented.

The network is starting to be more convergent, meaning that communication between the different actors is increasing. Specific questions or problems are addressed by efforts of actors working together in the network, for example participating in organizations like the US Water Alliance. Because the different actors in the US water technology sector are collaborating and communicating, the techno-economic network is a long network.

2.2 Technology main group

2.2.1 Federal US departments and agencies

According to the Global Water Market 2011 report, several federal US departments and agencies (e.g., US Army Corps of Engineers, US Department of Agriculture) are involved in the water sector (quality, management and technology) in the United States. The general role of the federal government in the water technology sector is to:

- Establish regulating water quality and technology standards and requirements;
- Enforce and monitor these regulations;
- Provide funding for states and local governments.

The most important federal agency within the American water technology sector is the United States Environmental Protection Agency (EPA). The EPA is the authority to establish and enforce environmental regulations. In the field of water technology, the Office of Water[21] is the main part of the EPA in the United States that is responsible for establishing and implementing water and wastewater-related advisories, guidelines and regulations. Four departments conduct the activities, initiatives and programs of EPA's Office of Water:

- Office of Drinking Water & Ground Water (water security)
- Office of Science and Technology (developing standards, guidelines)
- Office of Wetlands, Oceans & Watersheds (protection fresh water ecosystems)
- Office of Wastewater Management (e.g., biosolids, storm water, industrial effluent guidelines).[22]

Some of the states in the United States have received the authority from the EPA, for permitting, monitoring and enforcement (paragraph 1.2). Through several grants and funding programs, the EPA forms the main channel of federal funding to state and local water and wastewater systems (see paragraph 1.3).[23]

2.2.2 State water and wastewater agencies

According to my interviews, every state in the United States contains a "State EPA", directed by EPA's regional offices. In the field of water, those state environmental agencies are responsible for implementing the national drinking water limits and establishing wastewater discharge limits.

The implementation and enforcement varies by state and is often divided among state and local water and wastewater agencies. Also the names of responsible state agency vary (e.g., Virginia Department of

[21] http://water.epa.gov/
[22] http://www2.epa.gov/aboutepa/about-office-water
[23] Global Water Market 2011, United States of America (USA), Volume I

Environmental Quality (DEQ), Florida Department of Environmental Protection (DEP)). In some states drinking water supply is overseen by the Department of Public Health.

In general, the state water en wastewater agencies have supervision over:

- Water rights (prior appropriation or riparian rights);
- Allocation of water;
- Allocation of financial funding to water-related programs;
- Implementation of national legislation and regulation in water policy of the state (e.g., State Water Plan).

Therefore the approximately 55,000 water and 20,000 wastewater agencies are responsible for overseeing water supply, conservation, allocation, wastewater management, as well as the monitoring of water quality and quantity. As a result the water technology governance is fragmented.[24]

2.3 Science

The Science main group within the American water technology sector is responsible for developing knowledge and technologies feasible to address the challenges in the water industry. This group includes universities and research foundations and institutes that perform scientific and applied research.

The EPA stimulates R&D through grants. The Office of Research & Development is the scientific research arm of EPA and supports six integrated research programs that are established in cooperation with EPA offices, partners and stakeholders (e.g., state agencies, industry, utilities).

One of the programs is the Safe and Sustainable Water Resources (SSWR) Research Program that was created by integrating EPA's Drinking Water and Water Quality research programs. The new SSWR program has two major research themes that will provide innovative science and engineering solutions needed in order to maintain and protect the drinking water sources and ecosystems:

1) Sustainable Water Resources focuses on protecting water quality and restoring water resources and their designated uses (e.g., drinking water, aquatic life, recreation, industrial processes and so forth).
2) Sustainable Water Infrastructure Systems focuses on water infrastructure management approaches in order to optimize the use of water conservation, wastewater reuse, groundwater recharge, green infrastructure, energy conservation and resource recovery.[25. 26]

Other examples of research actors in the American water industry are:

- The US Army Corps of Engineers (USACE) Institute for Water Resources (IWR);[27]
- The Water Research Foundation;
- The Universities Council on Water Resources;
- The National Institutes for Water Resources;
- The WateReuse Research Foundation;
- The Center of Advanced Materials for the Purification of Water with Systems.

[24] Global Water Market 2011, United States of America (USA), Volume I, page158
[25] EPA, Office of Research and Development. Safe and Sustainable Water Resources Action plan 2012-2016, June 2012, http://www.epa.gov/research/docs/sswr-strap.pdf
[26] http://www.epa.gov/research/waterscience/
[27] http://www.iwr.usace.army.mil/About/MissionandVision.aspx

The Water Research Foundation is an organization that sponsors drinking water research and provide the information to their subscribers (e.g., manufactures, water utilities, consultancy) in the US and abroad (Europe, Canada). For the coming years the foundation has identified ten focus areas. These areas include research projects related to issues like hexavalent chromium contamination, the water and energy nexus, pharmaceutical products in drinking water and water system infrastructure. The Dutch KWR Watercycle Research Institute has a bilateral partnership with the foundation and served as a contractor for several research projects.[28]

The Universities Council on Water Resources (UOCWR) is an organization with member universities and non-academic institutions that are leading and at the forefront of water resources related research. The 54 National Institutes for Water Resources (NIWR) are located in every state at top land-grant universities and conduct water supply and resource research. Both organizations provide a useful overview of their members and institutes who are busy with water quality and water technology related research in the US.[29] One example of a university on the list of UOCWR and NIWR is Virginia Tech. Within the university, The Virginia Water Resources Research Center has an outstanding water resources program. The Environmental and Water Resources Engineering department is conducting water and wastewater treatment research and has three leading professors in drinking water technology. These three leading professors in drinking water technology were named in a list of the leading professors received from the American Water Works Association. Figure 4 shows the distribution of these leading drinking water professors at different universities throughout the United States. Every dot in the map represents a university with one or more professors. Based on this map it can be said that most of the leading universities and professors in the field of drinking water are located in the northeastern part of the United States. The information necessary to make the same figure of leading wastewater professors in the US could not be collected within the timeframe of this internship.

The Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS) is a National Science Foundation (NSF) science and technology center. Such centers conduct innovative and potentially transformative research. Ten universities (e.g., Yale University, Massachusetts Institute of Technology) and seven partners at national laboratories and water institutions (e.g., NSF, The National Risk Management Research Laboratory) in the US are working together in WaterCAMPWS. Research efforts focus on developing advanced materials (e.g., membranes, disinfectants, and sorbents), material treatments (e.g., coatings, particles) and chemical and biological processes.[30]

The WateReuse Foundation's research covers water reuse, recycling, reclamation and desalination. These themes include chemical contaminants, microbiological agents, treatment technologies, salinity management, public perception, economics and marketing.[31]

[28] http://www.waterrf.org/search/Results.aspx?k=KWR en http://www.waterrf.org/Pages/Index.aspx
[29] https://niwr.net/public/Migration/about-national-institutes-water-resources en http://ucowr.org/
[30] http://www.watercampws.uiuc.edu/index.php?menu_item_id=2
[31] http://www.watereuse.org/foundation/about

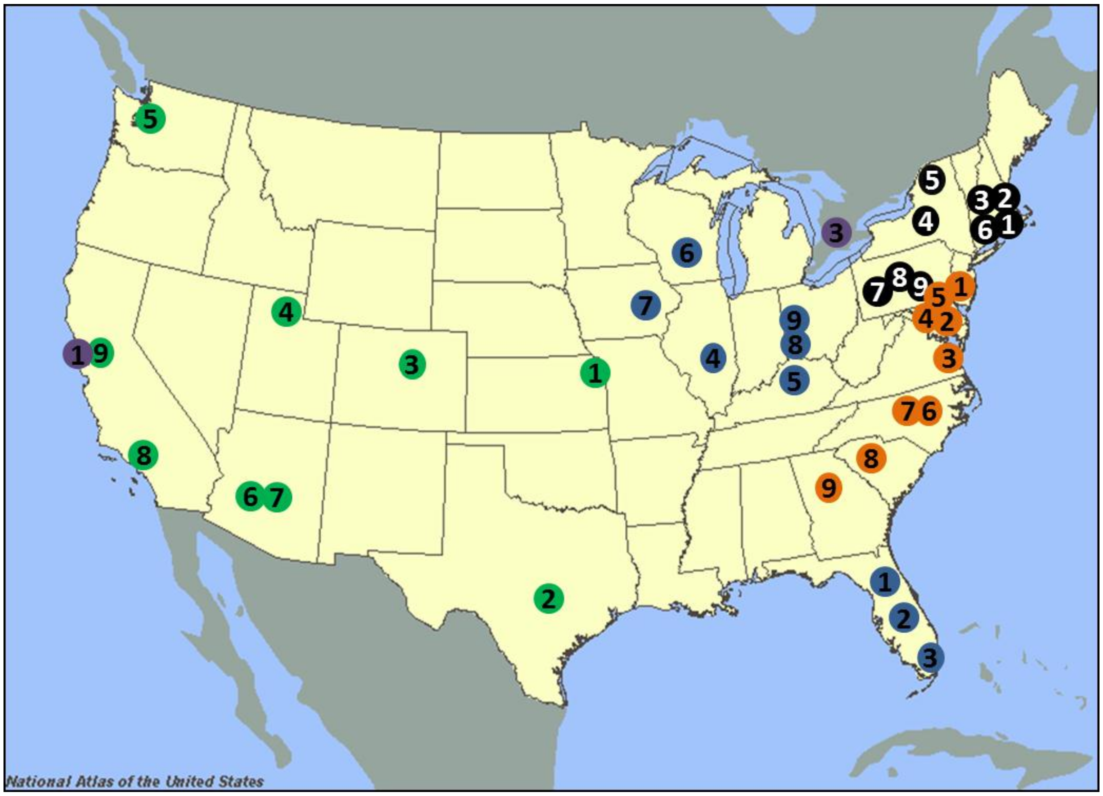

Figure 4: Distribution of leading drinking water professors at different universities in the United States.[32]

Table 2 is the legend of figure 4.

Table 2: Universities and their corresponding number as depicted in figure 4.[32]

Universities:	Nr.
Univ. of Massachusetts	1
Univ. of New Hampshire	2
Worcester Polytechnic Institute	3
Syracuse Univ.	4
Clarkson Univ.	5
Yale Univ.	6
Univ. of Pittsburgh	7
Penn State Univ.	8
Penn State (Harrisburg)	9

Universities:	Nr.
Florida	1
Univ. of Central Florida	2
Miami	3
Illinois	4
Kentucky	5
Wisconsin	6
Iowa	7
Cincinnati	8
Miami Univ.	9

Universities:	Nr.
UC-Berkeley	1
Univ. of Alaska	2
Univ. of Waterloo	3

Universities:	Nr.
Drexel Univ.	1
George Mason Univ.	2
Old Dominion Univ.	3
Virginia Tech	4
Johns Hopkins Univ.	5
North Carolina State Univ.	6
Duke Univ.	7
Clemson Univ.	8
Georgia Institute of Technology	9

Universities:	Nr.
Kansas Univ.	1
Univ. of Texas	2
Univ. of Colorado	3
Utah State Univ.	4
Univ. of Washington	5
Arizona State Univ.	6
Univ. of Arizona	7
UCLA	8
UC-Davis	9

32 AWWA, June 2013.

2.4 Market main group

2.4.1 Local water and wastewater utilities

Within the United States 40,000 local water and wastewater utilities are responsible for operating water supply and wastewater treatment systems. The majority are public utilities, owned by local municipalities, counties, cities or communities. Examples are the Philadelphia Water Department, the District of Columbia Water and Sewer Authority, and the New York City Water Board.

According to EPA's Drinking Water Information Systems statistics from 2008, approximately 160,000 public drinking water systems are located across the United States. Of these, about 53,000 are community water systems that collectively serve more than 295 million people in the US. The remaining non-community systems (e.g., non-transient and transient) serve about 20 million people. About 80% of the community systems are small or very small (e.g., serving 0-3,300 people).[33]

The United States has approximately 14,780 operational wastewater treatment facilities and 19,739 wastewater pipe systems as of 2008. These facilities are mostly publicly owned and serve about 220 million people. The majority are small wastewater treatment plants (e.g., 0 – 10,000 million gallons per day).[34]

The National Rural Water Association (NRWA) represents rural and small water and wastewater utilities.[35]

2.4.2 Customers

This actor represents end users of water in the American water technology market. Several definitions for water customer sectors are used. Generally, a top-level category is used to identify water customers, namely residential, commercial, institutional and industrial (CII sector).[36]

Residential customers include single family and multi-family houses in urban or rural areas, in municipalities and counties. The average American uses more than 54,684 gallons per year (207 m^3).

Commercial and institutional customers are grouped by the EPA, because the distinction between them can be somewhat arbitrary. Commercial customers include water users that provide or distribute a product or service, and institutional customers are water using establishments dedicated to public service. Therefore, commercial and institutional (CI) customers are defined by the EPA as any user other than residential accounts and those that can be clearly classified as industrial accounts. This definition includes: restaurants, office buildings, commercial and retail centers, hospitals, laboratories, golf courses, churches, utilities and infrastructure, food stores, hotels and motels and other subsectors.[37]

Following the CII sector definition, industrial water users are primarily manufactures or processors of materials. This does not include agriculture, which officially is counted separately. Water is essential for all industrial processes. Industrial water is used in different stages of the production process: fabrication, processing, washing and cooling. Without water there will be no production. The largest industrial water users in the US are the thermoelectric sector (e.g., energy production and cooling) and the manufacturing

[33] http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm,
[34] EPA, Clean watersheds needs survey 2008 report to Congress, 2010, page I-4 http://water.epa.gov/scitech/datait/databases/cwns/upload/cwns2008rtc.pdf
[35] http://www.nrwa.org/about/about.aspx
[36] Gleick, Peter, et. al. *Waste Not, Want Not*: The Potential for Urban Water Conservation in California . Pacific Institute. November 2003. http://www.pacinst.org/wp-content/uploads/2013/02/waste_not_want_not_full_report3.pdf
[37] EPA Watersense, Water efficiency in the Commercial and Institutional Sector: Consideration for a Watersense Program, Page 3, August 2009 http://www.epa.gov/WaterSense/docs/ci_whitepaper.pdf

sector. The manufacturing sector includes production of chemicals, paper, food, metal, wood and the pharmaceutical industry. The water use in the gas and oil industry is rising because of developments in shale gas production.

Table 2 describes the daily water withdrawals and consumption of water customers in the abovementioned sectors (e.g., industry, commercial). In total 346 billion gallons per day (BGD) is withdrawn; this water is returned to local water supplies and can be used again. The actual consumption is 100 billion gallons per day; this water is removed from the hydrologic source and cannot be used again.

Table 3: Summary of US Water Consumption and Withdrawals.[38]

100 BGD Consumption:	345 BGD Water Withdrawals:
- 80.8 billion for irrigation	- 138 billion for irrigation
- 7.1 billion for domestic uses	- 135 billion for thermoelectric power
- 3.3 billion for thermoelectric power production	- 48 billion for public and domestic supply
- 3.3 billion for industrial purposes	- 17 billion for industrial supply
- 3.3 billion for livestock	- 3.5 billion each for aquaculture, livestock and mining supply
- 1.2 billion for mining	
- 1.2 billion for commercial uses	- 3.5 billion other

2.4.3 Companies

This group of stakeholders represents the private water industry. The group includes the largest American private water and wastewater companies, as well as professional water service providers, equipment suppliers, manufactures and consultancy and engineering firms.

The National Association of Water Companies (NAWC) represents the individual companies in the private water industry. The members of the NAWC are privately owned and publicly traded (listed on stock market) drinking water utilities, wastewater services companies and also professional water contracting companies are all active and operating in the United States. They range from large companies owning, operating or partnering with hundreds of utilities in multiple states to individual utilities. According to the NAWC, the private water industry serves 15% of drinking and wastewater community directly and another 10% through existing partnerships with municipal and other public systems.

The Water and Wastewater Equipment Manufacturers Association (WWEMA) represent the equipment suppliers and manufactures.[39] The large water and wastewater companies in the US provide services in the field of drinking water (from surface or groundwater) and wastewater treatment for residential (e.g., civilians, municipalities), commercial (non-industrial companies), institutional and industrial customers. Examples are American Water, Veolia Water North America, United Water, Aqua Company, TonkaWater, Filtronics, Sensus, Blue Earth Labs, Aqua-Aerobic Systems, CH2M HILL and Global Water Technologies. At the Aquatech in November 2013 multiple US companies will exhibit their products and services in the RAI Amsterdam.[40]

[38] Kris Mayes presentation delivered at Workshop on Energy-Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slides 7 and 9.
[39] http://www.wwema.org/
[40] http://www.aquatechtrade.com/amsterdamen/pages/exhibitor-list.aspx

2.5 Nongovernmental organizations

Nongovernmental organizations fulfill their role between the main Technology, Market and Science group in the water technology sector in the United States. Their role is beneficial for the other actors by representing advocating, educating and conducting research from a market perspective.

The mentioned examples in the techno-economic network are:

- WateReuse Association;
- National Association of Clean Water Agencies (NACWA);
- Water Environmental Research Foundation (WERF);
- US Water Alliance;
- Alliance for Water Efficiency;
- Water Innovations Alliance (WIA);
- American Water Works Association (AWWA) (drinking water);
- Water Environment Federation (WEF) (water quality, wastewater).

3. American water industry trends

The United States is facing serious challenges (e.g., deteriorating infrastructure, emerging contaminants) therefore technology innovation needs to be accelerated. In March 2013, the EPA presented the Blueprint for Integrating Technology Innovation. The blueprint calls for national support of emerging technologies in water and wastewater treatment, testing, and reuse. Also, collaboration between academic, industry and government researchers need to be stimulated and made easier. In this blueprint several key market opportunities to employ innovative technology are identified.[41, 42]

Bringing emerging technologies to the forefront of the water technology market is difficult. Small innovative companies have a hard time to apply new technologies, because the regulatory authority slowly accepts these new technologies. The process usually takes 10 years, because of the complex system of federal, state and local requirements which complicates acceptance, adoption and use.

This chapter will briefly describe the most important trends in the water technology sector in the United States. Relevant examples are given of techniques and projects in the eastern part of the US.

3.1 Renewal of aging infrastructure

One of the top issues in the American water industry is the aging infrastructure.[43] In their 2013 report, the American Society of Civil Engineers (ASCE) graded both drinking water and wastewater infrastructure with a D (poor), which is a slight improvement in comparison with the score in 2009 (D^-).[44]

The definition for water and wastewater infrastructure in the United States includes all facilities and installations needed for the development and management of the water resources. For instance supply, treatment, provision and distribution of water to the end-users, as well as the collection, removal, treatment and discharge of sewage and wastewater (e.g., water and wastewater treatment plants, distribution pipelines, collection systems, tanks and other related equipment for transporting water and wastewater).

In 2012, the American Water Works Association (AWWA) concluded that more than $1 trillion nationwide is needed over the next 25 years in order to maintain and improve the <u>drinking water</u> infrastructure.[45] The EPA estimated that $384 billion in improvements (in pipelines, treatment plants, storage tanks and water distribution systems) are needed for the drinking water infrastructure in the United States over the next 20 years.[46]

On the <u>wastewater</u> side, EPA reported in 2008 that more than $300 billion is needed to improve the sewage collection and treatment infrastructure over the next 20 years in order to keep US surface waters safe and clean.[47]

Capital spending has not kept pace with needs for water and wastewater infrastructure, in part due to budget cuts in federal programs. It is estimated that the shift of financial burden to state and local

[41] EPA Blueprint For Integrating Technology Innovation, March 2013, http://water.epa.gov/blueprint.cfm
[42] http://news.wef.org/u-s-epa-introduces-blueprint-for-promoting-water-industry-innovations/
[43] The 2013 Strategic Directions in the US Water Industry Report, Black & Veatch June 2013
[44] The American Society of Civil Engineers 2013 Report Card for America's infrastructure
[45] The American Water Works Association report Buried No Longer February 2012
[46] EPA report Drinking Water Infrastructure Needs Survey and Assessment April 2013
[47] EPA Clean Watersheds Needs Survey 2008 Report to Congress

governments' will continue, assuming the bulk of the investment requirements in the coming decades will continue to rise, with local governments' paying an increasing share of the costs.

3.1.1 Drinking water infrastructure

Many of the components in the drinking water infrastructure are reaching the end of their useful life (normally 15 to 95 years). Failures in drinking water infrastructure can result in water disruptions, impediments to emergency response, and damage to other types of infrastructure. Broken water mains can damage roadways and structures (large sink holes) and hinder fire-control efforts. Unscheduled repair work to address emergency pipe failures may cause additional disruptions to transportation and commerce.

In addition, the condition of many miles of pipelines is unknown, with some pipes dating back to the Civil War era. Main breaks are becoming more common (240,000 water main breaks per year in the US) According to the ASCE seven billion gallons of treated drinking water are lost due to leaks in drinking water pipeline. This volume represents 15% of the US total daily drinking water production. Because of these problems, non-revenue water problems have become an important issue in the American water industry as well.

There is a huge need for system rehabilitation in the US by repairing, renewing and replacing distribution and transmission systems, treatment plants and storage and source intake facilities (e.g., reservoirs, wells). ASCE's Report Card conclusion states: "*America's drinking water systems are aging and must be upgraded or expanded to meet increasing federal and state environmental requirements that add to the funding crisis. Not meeting the investment needs of the next 20 years risks reversing the environmental, public health, and economic gains of the last three decades".*

3.1.2 Wastewater infrastructure

A lot of public sewer mains, equipment and wastewater treatment plants in the United States are approaching the end of their useful life. Investments will be required both in secondary and advanced wastewater treatment.

One symptom of the problem of aging pipes is represented by combined sewer overflows (CSOs). CSOs contain not only storm water but also untreated human and industrial waste, toxic materials, and debris when heavy rainfall produces a volume of water that exceeds the capacity of a combined sewer (see paragraph 3.4). CSOs affect more than 700 American cities and towns and represent a major challenge to the implementation of the Clean Water Act, which regulates sewage treatment.

The conclusion of the ASCE's Report Card is: "*Wastewater systems will incur growing costs over the next 20 years as they expand capacity to serve current and future growth. Other costs will result from stricter permitting standards, nutrient removal requirements, technology updates, and new process methods, among others. Beyond budget and financing options, the nation needs to consider multiple solutions to the wastewater infrastructure quandary."*

3.1.3 Dealing with aging water and wastewater infrastructure challenges

With respect to leaking pipes, the current rate of replacement or renewal of buried infrastructure is less than 1 percent per year for most utilities nationwide. In order to cope with the fast deteriorating water and sewer systems, public and private water and wastewater utilities in the US apply different kind of programs.

According to Black & Veatch, more than 90 percent of the American utilities are planning to have formal asset management programs in place or in progress by 2016. By using such structural condition assessments, infrastructure conditions can be determined in a cost-effective way, making it possible to identify worst-condition pipelines to be addressed first, avoiding potential failures and associated risks, damages, and costs (e.g., loss of treated water). One example in this regard is the City of Baltimore, Maryland. The City's Bureau of Water and Wastewater is implementing an asset management program in order to setup a strategic plan to address the aging infrastructure.[48]

After investigating infrastructure assets and conducting water and sewer system evaluation surveys, rehabilitation programs are the next step for utilities to improve their infrastructure. The Washington Suburban Sanitary Commission (WSSC) is the water and wastewater utility in Prince George's and Montgomery County in Maryland (counties surrounding Washington D.C.). The utility is working on their sewer repair, replacement and rehabilitation program since 2005. In order to reduce the amount of sanitary sewer overflows, which are unintentional discharges of raw sewage, WSSC is planning to invest $1.6 billion. To improve the quality and conditions of main sewer pipes, manholes and laterals, pipe lining, grouting, armoring pipe bursting, relocation and replacement techniques are used.[49]

Resiliency of the existing (aging) water and wastewater infrastructure has become an important issue after Super Storm Sandy hit parts of the East Coast in 2012. This extreme weather event showed how vulnerable the water and wastewater infrastructure is in the United States. In order to achieve greater resiliency, all of the American states except Louisiana and two Canadian provinces (Ontario, Alberta) have signed a Mutual Aid Agreement (MAA) in order to participate in WARN, the Water and Wastewater Agency Response Network. The voluntary members of this network (e.g., local water and wastewater agencies) offer each other the necessary help (e.g., equipment, trained professionals) to be able to manage disasters without federal or state aid for at least 24 to 72 hours. WARN has been successfully used between the affected states (NY, PA, NJ, MA) during Super Storm Sandy.[50]

The City of New York is making efforts to increase the flood resistance of drinking water and wastewater infrastructure. First an assessment has been conducted to identify which wastewater infrastructures are at risk for sea level rise or severe storms. Next an action plan was developed that includes several adaptation strategies, advising that water and wastewater infrastructure should be built in such a way to be able to cope with a once in a hundred year storm plus 30 inches of sea level rise.[51]

New and more cost effective assessments (e.g., leak detection, prediction models of condition systems, asset management models) and rehabilitation techniques are needed. Increased emphasis should be placed on green infrastructure for storm water management and decentralized approaches (e.g., downsizing to small piping systems) that can reduce pumping and treatments costs.

3.2 Water recycling and reuse

Water reuse and the use of reclaimed water are widely applied and are increasing in the US. Water reuse is generally defined as the use of municipal wastewater that has been treated to meet specific quality criteria with the intent of being used for a range of beneficial purposes (reclaimed water). The term water recycling is generally used synonymously with water reclamation and water reuse.[52]

It is estimated that nationally approximately 2.5 billion of gallons per day of treated wastewater is reused in the U.S and the reuse volume is growing with an estimated 15% per year. 90% of the volume of reused

[48] Presentation Rudolph Chow, Joint Spring Meeting CSAWWA & CWEA, May 2013
[49] Presentation Mark Behe, Joint Spring Meeting CSAWWA & CWEA, May 2013
[50] Presentation Terry Biederman, Water Innovation Alliance Water 2.0 Event, May 2013
[51] Presentation Pinar Balci, ACCO 2013 Rising Seas Summit, June 2013
[52] EPA 2012 Guidelines for Water Reuse, September 2012

water takes places in four states: California, Florida, Arizona and Texas.[53] In the Water Stress Index as defined by Pfister in 2009, these states have the highest scores on a scale from 0 till 1 (e.g., Arizona 0.998), meaning that the water withdrawals are relatively high in comparison with the hydrological availability of water and while taking into account the variability in precipitation, causing water stress and scarcity.[54]

Agricultural irrigation is responsible for the largest amount of water reuse in the US. With a growing abundance of reclaimed wastewater, reused water is becoming a reliable alternative water source. The trend in areas where the groundwater table is dropping is the recharge of aquifers, for example in states like Florida and California. In such ground water recharge projects, recycled water is spread or injected into ground water aquifers. In this way ground water supplies can be replenished and fresh water barriers against salt intrusion are established. The state of Florida is very supportive of water reuse, evidenced by incentives and regulations (www.dep.state.fl.us/water/reuse/flprog.htm).

The uses of recycled or reclaimed water include:

- Agricultural irrigation (e.g., crop irrigation);
- Landscape irrigation (e.g., parks, golf courses);
- Industrial recycling and reuse (e.g., cooling water, process water);
- Groundwater recharge (e.g., salt water intrusion control, groundwater replenishment);
- Recreation/environmental uses (e.g., marsh enhancement);
- Non-potable uses (e.g., fire protection, toilet flushing);
- Potable uses (e.g., indirectly blending in water supply reservoirs and groundwater or directly into drinking water distribution system).[55]

<u>Industrial reuse</u> continues to gather momentum and onsite water reuse is becoming one of the most adaptable approaches by industries. Driven by the need to secure their water resources for industrial processes, water intensive industries (e.g., computer chip and car parts manufactures) are moving their facilities to areas where water is not a scarce liquid.

My interviews also show that "<u>sewer mining</u>" is the latest trend in industrial water reuse. This practice is different from wastewater or sewage mining. During sewer mining, satellite or decentralized wastewater treatments plants tap water from a sewer collection system and treat the water on-site to the necessary water quality for local reuse and recycling applications (e.g., industrial process, cooling, irrigation). The process residuals are returned to the collection system and treated at centralized treatment facilities. Sewer mining as a water reuse technique is beneficial in several ways, because it enhances collection system capacity, thereby avoiding sanitary overflows and increases capacity of the drinking water supply by using less tap water.

Most and best used techniques for sewer mining are decentralized membrane systems. After conducting research American Water concluded that membrane bioreactors (MBR) in combination with ultraviolet disinfection, produces the best water quality in order to be used as reclaimed water. The fact that MBR is becoming more popular in wastewater treatment is acknowledged by the interviews. MBR application research conducted for American Water showed a reduction of 40 percent in energy intensity and improvement of effluent quality for nitrogen and phosphorus removal.[56]

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[53] Presentation Guy Carpenter, Reclaimed Water Trends Nationally and Internationally, February 2010
[54] See Water Stress Index as shown in the USA map on http://growingblue.com/the-growing-blue-tool/
[55] Asano, et al., Water Reuse: Issues, Technologies, and Applications, 2006
[56] Innovation & Environmental Stewardship: Review of Significant Water Industry Trends, report American Water

In the Mid-Atlantic region drivers for water reuse are:

- Water use restrictions;
- Regulations regarding Total Maximum Daily Loads (TMDLs);
- Drought conditions (e.g., groundwater reservoir levels are dropping);

Reuse of water can enhance energy conservation (e.g., reduced pumping requirements) and water quality management (e.g., stream flow augmentation, nutrient management). Mid-Atlantic water reuse projects in Virginia and Maryland include the Upper Occoquan Service Authority that uses physical-chemical advanced treatment to discharge 42 million gallons per day (MGD) into Lake Occoquan for indirect potable uses. Other projects are related to landscape irrigation and the cooling of data centers. New data centers will be opened in the Mid-Atlantic region that will need a lot of water for cooling.

In the State of Colorado, the Denver Water Recycling Plant improves the water quality of treated wastewater from the Metro Wastewater treatment facility, so that water can be reused for Xcel Energy's cooling towers and for the irrigation of parks, golf courses, schools and the zoo. Technologies like biological aerated filter, flocculation, sedimentation and filter beds of anthracite are used to treat the water for reuse.

There are significant needs for technologies and approaches that foster substantially greater water reuse, or sewer mining, which in turn can reduce pollution and conserve energy. Utilities, municipalities and the industrial sector are seeking ways to implement environmentally friendly en economically feasible solutions to reserve water resources and meet demand.

3.3 Desalination

Although the US is the second largest desalination market in the world after Saudi Arabia, desalination is not widely used at a large scale in the US. However, desalination is gaining more attention, particularly in the arid coastal regions in the US where production and disposal is more feasible.[57]

Desalination can be described as the process of purifying salt or brackish water into fresh water. There are different technologies to remove dissolved salts from water employed worldwide, like thermal technology (e.g., distillation) and membrane technology (e.g., reverse osmosis). Challenges include brine disposal, pretreatment optimization, energy conservation and overall productivity of membrane systems.

In the US the majority of the plants use membrane technology which is used both to convert seawater into drinking water and for treating brackish groundwater. The majority of US desalination plants treat brackish water, boiler feed water or process water and most of them (80%) are located in states with water scarcity like California, Texas and Florida.[58]

According to my interviews, membrane technologies are used in the eastern part of the US to desalinate brackish water, mostly driven by a shortage in water or groundwater threatened by salt intrusion.

In the Orange County Water District, CA, a large UV-oxidation facility was built to have a groundwater replenishment system that indirectly reuse potable water (IPR) by injecting the treated water into local aquifers in order to prevent salt water intrusion. This plant uses microfiltration (MF), reverse osmosis (RO)

[58] Global Water Intelligence 2010, Volume 1, United States

and an ultraviolet (UV) oxidation/disinfection system.[59] In this way a new water supply and a fresh water barrier for the salt water is achieved.

In the field of membrane technology, research is conducted in the field of:

- Forward osmosis (e.g., increasing flux to make surface of membranes more efficient);
- Selective membrane technologies;
- Nanotechnologies.

An interesting new innovative product in the field of membranes feasible for desalination is Perforene™ material, which is developed by Lockheed Martin. This molecular filtration solution is based on the Perforene membrane that features holes of one nanometer or less in a graphene sheet. In this way the flow-through of water is improved making it more cost-effective than current reverse osmosis systems. This membrane can be adjusted in order to filter other specific size particles of interest.[60]

Another interesting innovative technique is the Okeanos WaterChip™. Although this product is still under development (up scaling fase) this Waterchip uses a micro-electrochemical process with radical energy efficiency to desalinate millions of liters at a time. It has the potential to produce desalinated water at lower energy consumption rates than reverse osmosis for low flow rates.[61]

The uncertainty how environmental impacts are addressed in the permitting processes is a barrier for implementing desalination technology in the US. As does the long period of time it takes to implement new technology.[62]

3.4 Storm water management

An important issue in the American water technology sector is storm water management. In 2012, EPA released an integrated storm water and wastewater framework to help municipalities manage regulatory obligations and financial constraints.[63] Stricter federal and state regulations for wastewater and storm water systems are the main drivers for improving such systems. The goal is to improve water quality of the American watersheds. Recently, the EPA also launched the national storm water calculator in order to help manage storm water runoff.[64]

Also, the EPA and the US Justice Department have made eliminating combined sewer overflows (CSOs) a national priority. During periods of significant rainfall, the capacity of a combined sewer may be exceeded. Release of this excess flow is necessary to prevent flooding in homes, basements, businesses, and streets. But it is bad for the water quality of those rivers and streams. CSOs affect more than 700 American cities and towns and represent a major challenge to the implementation of the Clean Water Act.

Since 2007, these agencies have signed consent decrees under the Clean Water Act requiring cities operating publicly owned treatment works (POTWs) to invest more than $15 billion in new pipes, plants, and equipment to eliminate CSOs. Some cities, however, are employing nonstructural solutions to address the problem of CSOs at lower overall cost and with good results for the environment.

[59] www.gwrsystem.com/the-process.html
[60] http://www.lockheedmartin.com/us/mst/features/2013/130322-wanted-clean-drinking-water.html
[61] http://www.waterworld.com/articles/2013/07/membrane-free-desalination-chip-a-troll-at-the-bridge.html
[62] WateReuse Research Foundation
[63] http://www.wef.org/publications/page_wet.aspx?id=8589935179&page=news first two news highlights
[64] http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/4dc74e69023f3ccf85257bb2005558e8!OpenDocument

Another threat for surface and groundwater quality is the discharge of 850 billion gallons of untreated sewage each year into surface waters, because of aging wastewater management systems. Also yearly 10 billion gallons of raw sewage is released as a result of sanitary sewer overflows (SSOs). These are occasional unintentional discharges of raw sewage from municipal sanitary sewers due to blockages, line breaks or sewer defects that allow storm water and groundwater to overload the system. The EPA estimates that there are at least 23,000 to 75,000 SSOs per year.

There is a need for technologies that address nonpoint sources of pollution. There is a demand for storm water control mechanisms and green infrastructure (e.g., recharge basins, rapid infiltration beds). On the West Coast, the City of Portland, Oregon, is one of the cities who are at the forefront of storm water management.[65] In the eastern part of the US, the Chesapeake Bay cleanup program is a huge driver for implementing green infrastructure, storm water management tools and new innovative technologies for reducing total maximum dailylLoads (TMDLs) from wastewater treatment plants (WWTPs). States in the Chesapeake Bay watershed are also working on a new agreement between the states to reduce TMDL by October 2013. In order to reduce CSOs with 98%, DC Water is conducting the Clean Rivers Project, building massive underground tunnels in the coming years, which will store combined sewage during heavy rainfall. After the storm subsides, the diluted sewage water in the storage tunnels will be released to the Blue Plains advance wastewater treatment plant (AWTP). See for more information the Chesapeake Bay Program.[66]

As part of the Great Lakes Restoration Initiative in the Midwest region, the EPA offers new grants for green infrastructure projects (e.g., constructed wetlands, green roofs) in shoreline cities for the year 2013. From 2010 until 2012, almost 1 billion USD was provided by the taskforce which includes eleven federal agencies.[67, 68]

In the State of Pennsylvania, the City of Lancaster and the City of Philadelphia are working intensely to implement green infrastructure (e.g., green roofs, rain gardens, infiltration and bioretenion system) to capture and retain storm water. The City of New York also has plans to do so.[69]

3.5 Nutrient recovery and removal

According to my interviews, nutrient recovery (e.g., wastewater mining) will be an important topic in the United States in the coming years. Driven by the need to reduce nutrient pollution because of stricter regulations in surface water and drinking water supplies (caused by e.g., nitrogen, phosphorous), emerging technologies that can treat as well as recover nutrients from water and wastewater will be needed in the United States. It is all about making an economical feasible case to recover and reuse the materials or water.

One example of a successful implementation of an innovative technology for phosphorous and nitrogen recovery in the eastern part of the United States, is the Struvite Recovery Facility of the Hampton Roads Sanitation District (HRSD) in the state of Virginia[70]. After recovering the nutrients from the wastewater recycle stream, including nitrogen and phosphorous, they are transformed into an environmentally friendly and commercially available fertilizer. This is done by using the Ostara's Pearl Nutrient Recovery Process[71], which produces Crystal Green fertilizer. This nutrient recovery facility was officially started in

[65] http://www.portlandoregon.gov/bes/34598
[66] http://www.chesapeakebay.net/
[67] http://www.glri.us
[68] http://yosemite.epa.gov/opa/admpress.nsf/0/C9481CD7E86EDE5385257BB4005A80C6
[69] Presentation Pinar Balci, ACCO 2013 Rising Seas Summit, June 2013
[70] http://www.hrsd.com/pdf/News%20Releases%2010/HRSD%20News%20Release%20FINAL.pdf
[71] Ostara's Pearl process (www.ostara.com/technology)

May 2010 and won the Innovation Award from The National Council of Public-Private Partnerships (NCPPP).[72]

In December 2010 the Water Environment Research Foundation published the report Nutrient Recovery State of the Knowledge. This report stated that, besides nutrient recovery, *"wastewater mining"* also includes the recovery of various metals (from wastewater biosolids) and other useful materials, such as thermoplastics, ammonia, hydrogen and so forth. In this way wastewater becomes a renewable source.[73]

Furthermore, the EPA is considering setting more-stringent effluent limits for nutrients in waters treated at wastewater treatment facilities. Therefore, advanced technologies for nutrient removal and recovery are needed in the US. However, many wastewater treatment plants in the US only apply secondary treatment (e.g., activated sludge and secondary sedimentation tanks) in order to remove organic materials. DC Water is upgrading and expanding the nitrification and denitrification system in order to apply enhanced nutrient removal to reach the goal of 4 milligram of nitrogen per liter. Therefore, DC Water is researching the possibilities for mainstream deammonification with annamox bacteria.[74]

3.6 Disinfection

Worldwide the need for disinfection of water and wastewater treatment processes is increasing, driven by industrialization, urbanization and more stringent legislation. New analysis from Frost & Sullivan Global Water and Wastewater Disinfection Systems Market, finds that the market earned revenues of $1.94 billion in 2012 and estimates this to reach $2.96 billion in 2019.[75]

In the US many utilities are considering changes in treatment process to avoid noncompliance with new disinfection byproduct (DBP) rules. The stage II of DBP regulations therefore is an important driver for technological changes. Choices in drinking water purification system are mainly based on safety and health arguments.[76]

According to my interviews, a transition is visible in disinfection methods in the American drinking water sector; from only chlorine disinfection to upcoming ultraviolet radiation systems in combination with chloramines. Also advanced oxidation, ozonation, electro-chlorination, biological filtration and other disinfection methods are becoming more popular in the US. Up till now disinfection has always been combined with chloramines or chlorine.

So far, UV and advanced oxidation (e.g., AOP) are not applied widely throughout the US. UV and advanced oxidation can be used as disinfection method or as a polishing step, removing pharmaceuticals, pathogens, nitrosamines, industrial chemicals and other contaminants. These technologies are often used for direct potable reuse of wastewater, to remove specific compounds from groundwater and for controlling bad taste, odor and color issues in drinking water.

3.7 Smart water network

A smart water network is a fully integrated set of products, solutions and systems that enable water utilities to remotely and continuously monitor and diagnose problems, preemptively prioritize and manage maintenance issues, and control and optimize all aspects of the drinking water distribution network using data-driven insights. The use of smart water networks also help utilities to comply with regulatory and

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[72] www.hrsd.com/pdf/News%20Releases%2010/NCPPP%20Award%20-%20HRSD%20_%20Ostara.pdf).
[73] WERF, Nutrient Recovery State of the Knowledge, December 2010
[74] http://www.iweasite.org/Conferences/gvt_affairs/gac_12_deammonification.pdf
[75] http://www.prnewswire.com/news-releases/frost--sullivan-enormous-growth-potential-for-the-water-and-wastewater-disinfection-systems-market-212868061.html
[76] Opflow article, Disinfection, source water quality drives treatment selection, Steve Hubbs, April 2013

policy requirements on water quality and conservations in a more transparent way. Customers can use available information and tools to make informed choices about their behaviors and water use patterns.[77]

Based on my interviews and events, smart water networks are growing in the US. Five drivers in the water sectors for implementing smart water networks can be identified:

- Smart Cities;
- Net Zero Water;
- Aging, failing and insufficient, inefficient infrastructure;
- Water, energy and food security;
- Climate volatility;[78]

Required technologies for smart water networks are:

- Measurement and sensing devices (e.g., smart water meters, electromagnetic and acoustic sensors);
- Real-time communication channels for gathering data from sensing devices and instructing devices with actions like remote shutoff;
- Basic data management software for processing data and visualization with GIS, spreadsheets or graphs (e.g., work order management and customer information systems);
- Real-time data analytics and modeling software for real-time monitoring and analyzing responses, changes to better understand potential impacts;
- Automation and control tools for conducting network management task remotely and automatically (e.g., SCADA systems integrating with smart water network).[78]

One consequence of the aging infrastructure is non-revenue water. This water has been treated in water treatment plants and is pumped into the distribution system, but is lost due to leaks in the aging distribution system, therefore it never reaches customers. This loss forms a key challenge in the water industry in the US, as the national average for non-revenue water is 20 percent. Improving system metering, data integrity, leak monitoring and control will improve system performance and reduce costs (e.g., costs for treating and pumping water). These efforts will also conserve precious water supplies.

The main challenge of a digital utility is how to cope with a flow of data and water. Engineering and consultancy firms are helping water utilities to implement and to develop software for analyzing and making data more understandable and visible. Companies like Innovyze, Sensus, GE Water and Power IBM, Neptune and CH2M HILL offer utilities management solutions, meters, modeling software and other technologies to help implement the available technologies in order to create smart water networks.

By making water systems smarter, utilities will be able to understand their buried assets, optimize their performance and life span, making them more proactive instead of reactive. Efforts are made to implement smart water networks in the water industry.

A case study in this regard is DC Water, which in collaboration with IBM, has implemented software to help gaining greater visibility into its assets, improving their asset's reliability and lifespan. By using advanced spatial analytics that deliver real-time information DC Water is better able to predict potential problems and occurrences based on location, time, weather and historical events.[79]

[77] Water 20/20: Bringing Smart Water Networks Into Focus, Report, Sensus, December 2012
[78] Presentation Paul Boulos, CEO Innovyze, Water 2.0, Water Innovation Alliance, May 2013
[79] http://www-01.ibm.com/software/success/cssdb.nsf/CS/LWIS-88TQGT

3.8 Water & energy nexus

The production of water and energy are linked together in an inextricable way. To describe it in simple terms: water is needed to produce energy and energy is needed to produce water. Challenges that increase pressure on affordable water and energy are: climate change, limited water resources, increased water treatment requirements and pollution from energy exploration. [80, 81] In the US water and wastewater utilities use significant amounts of electricity. Four percent of the nationwide power generation is consumed by the 155,000 public drinking water and 16,000 wastewater facilities.[82] Moreover, the electricity industry is the second largest user of water in the United States.

Water reuse, climate change and the water & energy nexus are closely related. First of all reuse of water is needed in order to have enough water resources in the coming years. Climate change will affect the appropriation of water (water resources) and water quality, because of a greater occurrence rate of extreme events such as severe droughts or flooding events. By using less water through higher efficiency, less leakages and so forth, energy can be saved for the production of water, which saves energy and reduces CO2 emissions. Energy conservation and recovery technologies are needed to reduce energy consumption and treatment costs. The conservation of water is also an effective and environmentally friendly way to reduce demand for water and conserve energy (e.g., less energy need for treatment and supply).

Turning water and wastewater facilities into net zero energy consumers or net producers of energy is the latest trend in the American water technology market. By installing renewable energy technologies (e.g., geothermal energy, geo-exchange, and sewer heat-recovery systems), heat is captured from wastewater and then reused to help heating other buildings or complexes. Another ways to become a net zero energy consuming wastewater facility is by producing energy by anaerobic digestion of sludge and other organic materials. If a plant meets certain standards it can be classified as a class A, B or C type of product. For example, The Blue Plains WWTP in D.C. will be using thermal hydrolysis and anaerobic digesters in 2014. When completed, it will be the largest thermal hydrolysis plant in the world. The process "pressure-cooks" the solids left over after wastewater treatment to produce combined heat and power-generating 13 MW of electricity, cutting power consumption by a third. These vessels can also ingest scraps, fats and grease to generate power. Besides producing energy this process will also create a Class A biosolid product from sludge that can be sold for filling up golf courses or as a substitute for fertilizer.[83]

3.9 Emerging contaminants

According to my interviews, monitoring and removal of emerging contaminants will be a trending topic in the US water technology market in the coming years. These contaminants of emerging concern (CECs) are often unregulated and occur in untreated and fully treated water and wastewater. They can be described as chemicals or materials characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards.[84] Examples of emerging contaminants are pharmaceutical and personal care products (PPCPs), endocrine disrupting compounds (EDCs), pesticides, artificial chemicals, toxins, nanomaterials and perfluorinated compounds. Pharmaceuticals include prescription drugs, medicines and veterinary drugs. Personal care products include soaps, fragrances and cosmetics.

[80] Innovation & Environmental Stewardship: Review of Significant Water Industry Trends, report American Water
[81] http://www.acus.org/files/EnergyEnvironment/062212_EEP_FuelingAmericaEnergyWaterNexus.pdf
[82] http://www.acus.org/files/publication_pdfs/403/ee121101waterneeds.pdf Atlantic Council report, October 2012
[83] http://www.dcwater.com/news/publications/Blue_Plains_Plant_brochure.pdf
[84] http://www.epa.gov/fedfac/documents/emerging_contaminants.htm

Because of the Safe Drinking Water Act Amendments of 1996, the EPA is also implementing new or stricter drinking water limits on numerous contaminants, including arsenic, radioactive contaminants, and microbial and disinfection by products. Hexavalent Chromium is getting a lot attention in US, it is the most toxic form (cancer causing). There are regulations for total byproducts but not for specific hexavalent chromium.

The findings from new research will be used to set up regulations on how to deal with those substances in the different types of water, so that treatment requirements can be established in the future. The EPA is requiring water utilities to sample for about 20 new emerging contaminants in 2013. The contaminant candidate list (CCL) identifies priority contaminants for regulatory decision-making and information collection. CCL 3 is a list of contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations, that are known or anticipated to occur in public water systems, and which may require regulation under the Safe Drinking Water Act (SDWA). CCL 3 includes 104 chemical or chemical groups and 12 microbiological contaminants that are known or anticipated to occur in public water systems.[85]

[85] http://water.epa.gov/scitech/drinkingwater/dws/ccl/ccl3.cfm

4. US Water Clusters & Technology Initiatives

In recent years water companies, universities and other organizations have established multiple clusters in the field of water technology in the US. Besides established clusters, water technology initiatives are started in other regions and cities including in Canada. These clusters offer opportunities for scientific research collaborations, commercialize technologies and research and development partnerships.

4.1 Identifying water technology clusters

The EPA is coordinating and assisting water clusters and initiatives in the US. During my visit to the American Water Works Association (AWWA) Annual Conference & Exposition 2013 (ACE13) in Denver, Colorado, a presentation was given by the EPA's Director of the Environmental Technology Innovation Clusters Program in the Office of Research and Development, Sally Gutierrez. In her presentation *"A New Hope: The Role of Water Technology Innovation Clusters*", she explained that there is a need for clustering in the American water technology sector because the sector is fragmented. Water clusters form a solution for this problem.

The definition of a cluster is: *"a geographic concentration of interconnected firms (business suppliers, service providers) and supporting institutions (government, investors, universities etc.) that work together in an organized matter to promote economic growth and technological innovation".* The EPA is involved by initiating clusters and initiatives and is busy identifying emerging groups. The presentation of Sally Gutierrez showed a map of ten water clusters in the United States. Most of them are very recently initiated and established (0 - 3 years). Wastewater treatment, industrial water treatment and water use management are the most important technological areas of the clusters.

Besides these ten recently established clusters, other water technology initiatives were identified with information from my interviews, visits to events and the Dutch government (e.g., consulates Chicago, Toronto). In this way, eight other water technology initiatives were identified. Based on the collected information figure 5 was composed. The figure shows ten recent established water clusters as presented by the EPA (green dots with black capital letters) and eight other water technology initiatives (orange dots with black numbers). Notable to mention is the fact that half of the clusters are located in the northeastern part of the US.

In the following paragraphs the ten clusters in the eastern states of the United States will be examined into further detail. Due to the scope of this research the following clusters are not described in further detail:

- The Blue TechValley in Central and San Joaquin Valleys, California;
- San Francisco;
- Las Vegas Cluster Effort, Nevada;
- Arizona Cluster Effort in Tucson, Arizona;
- Colorado Water Innovation Cluster;
- Vancouver, Canada;
- WaterTap Ontario, Canada;
- Portland Oregon.

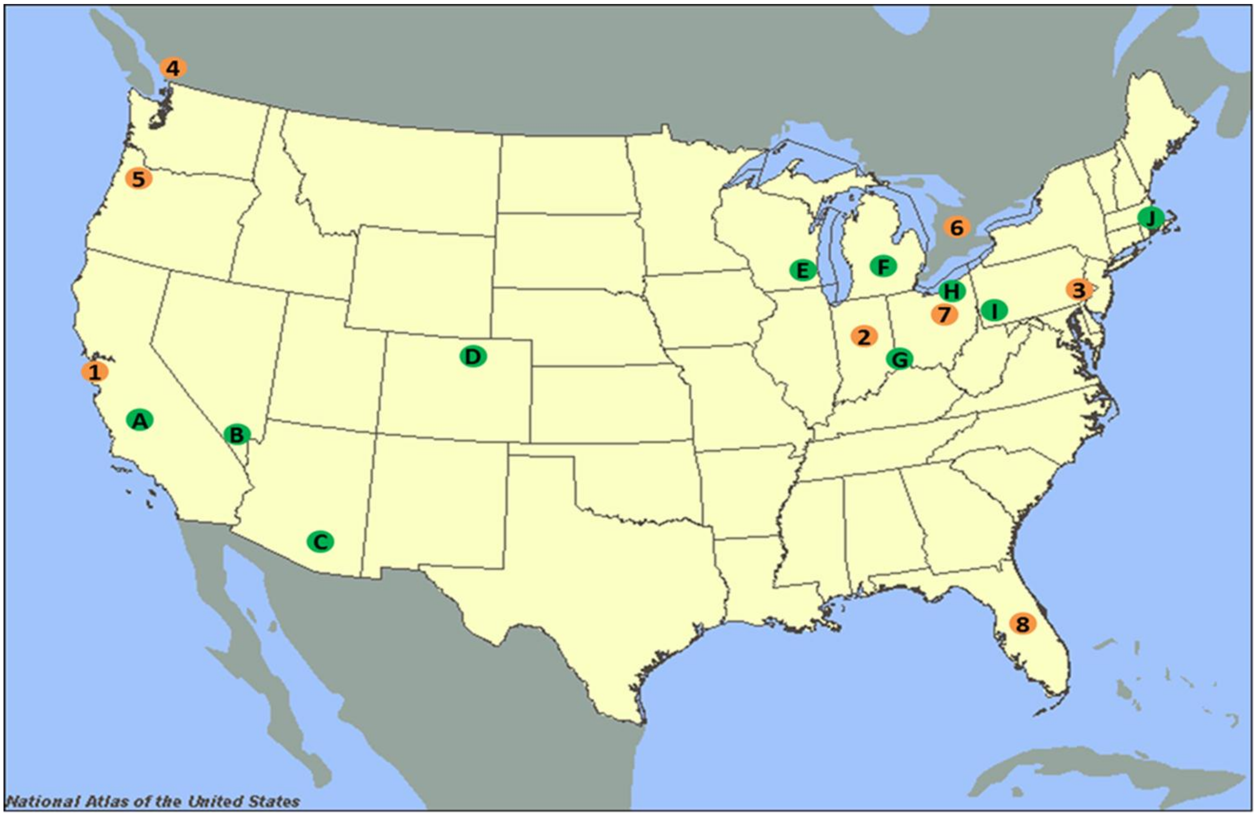

Figure 5: US water clusters and technology initiatives.

Table 4 provides a list of the depicted cluster and initiatives in figure 5.

Table 4: List of water clusters and technology initiatives

Established Water Clusters EPA	Capital Letter	Water technology initiatives	Number
The Blue TechValley	A	San Francisco	1
Las Vegas Cluster Effort	B	Living Laboratory Indianapolis	2
Arizona Cluster Effort	C	Philadelphia	3
Colorado Water Innovation Cluster	D	Vancouver, Canada	4
Milwaukee Water Council	E	Portland	5
Green Jobs for Blue Waters Initiative	F	WaterTap Ontario, Canada	6
Confluence WTIC	G	The Akron Water Initiative	7
NorTech Water	H	Florida	8
Water Economy Network	I		
Massachusetts Water Innovation Initiative	J		

4.2 Confluence Water Technology Innovation Cluster

In January 2011, the Confluence Water Technology Innovation Cluster (CWTIC) was initiated in Dayton, Cincinnati, northern Kentucky and southeast Indiana by the US Small Business Administration (SBA) and the US Environmental Protection Agency (EPA). The goal of clustering public and private entities in the Ohio River Valley Region is to develop and commercialize innovative water technologies. About 250 water-related companies are located in this region.

CWTIC is an organized network nonprofit organization of public and private companies (small or large) and supporting governments (local government, economic development agencies, universities, investors and others) that work together to promote economic growth and technological innovation. They intended to have intellectual development first. The Board Members represent all the organizations from across the geographic Ohio River Valley Region that collaborates together within CWTIC. Examples of official partners of CWTIC are:

- Greater Cincinnati Water Works (GCWW)
- Xylem, Inc.
- University of Dayton
- University of Cincinnati
- Metropolitan Sewer District of Greater Cincinnati (MSDGC)
- Northern Kentucky University
- General Electric Power & Water

The EPA serves as an ex-officio member of the Confluence's board, offering technical expertise and advice when solicited. EPA Cincinnati is also supporting CWTIC with their regional water research, development and deployment laboratory and multiple state of the art research facilities (e.g., AWBERC) in Ohio.[86, 87]

EPA Cincinnati researchers are seeking collaborations with external scientist and engineers to find solutions for wastewater, storm water, drinking water, water reuse and watershed management challenges.[88]

Examples of the recent accomplishments and activities of CWTIC:

- GCWW and MSDGC announced Cincinnati water tech accelerator;
- Tri State Process Harmonization signed (January 2013);[89]
- Cincinnati announces Collaboration for establishing Global Water Technology Hub;[90]
- Confluence Water Symposium 2013;
- MSDGC marketing Metro West property to industrial water users.[91]

[86] http://www.epa.gov/nrmrl/watercluster/WTIC_coordinate.html (visited on 06/20/2013)
[87] Presentation Evelyn Hartzell, Cincinnati EPA Water Cluster Stakeholder Engagement Coordinator, May 2013
[88] http://www.epa.gov/nrmrl/watercluster/collaborative_research.html
[89] http://watercluster.org/wordpress/wp-content/uploads/2013/01/Tri-State-Agreement-Article-Biz-Courier1.pdf
[90] http://www.cincinnati-oh.gov/water/assets/File/Technology_Hub.pdf
[91] http://www.cincinnati-oh.gov/water/linkservid/021CC55D-C9DA-604C-711377FB000E4062/showMeta/0/

4.3 Milwaukee Water Council

The Water Council in Milwaukee, Wisconsin was created by leaders in business and education in 2007 to bring the region's water technology companies and universities together. The goal of the Milwaukee Water Council is to build cross-sector and global research and business partnerships, develop training programs and solve the local and global water challenges with newly developed and deployed innovative water technologies. It's established from a more business point of view and its goal is to become a water technology hub and attract business and companies. More than 130 water technology companies are located in the Milwaukee area. These businesses manufacture equipment (e.g., pumps, valves and meters), deal with water purification problems, address wastewater treatment problems and support the reuse of water.

The Board Members of this nonprofit organization consists of leaders representing the full cycle of water (business, academia, government, NGOs, environmental and investment groups). Currently the Milwaukee Water Council has 120 dues-paying members (also nonprofit organizations) that include:

- University of Wisconsin-Milwaukee
    - School of Freshwater Sciences
    - Great Lake Water Institute
- University of Wisconsin Whitewater
    - Water Business Management
- Concordia University
- Marquette University
- Veolia Water
- CH2MHILL
- Badger Meter (water meters)
- A.O. Smith (water heaters)
- Kohler (faucets and toilets)

The City of Milwaukee wants to create an environment for companies developing new water technologies by leveraging its water facilities for testing and piloting. For example, the Milwaukee Metropolitan Sewerage District (MMSD) provides on-the-ground testing support for new technologies in their treatment facilities. Veolia Water and Veolia Innovation Accelerator (VIA) are promoting the development and deployment of leading clean technologies in partnership with start-up companies. So far, data indicate that there has been an $80 million investment in buildings and infrastructure from a variety of sources.

In March 2013, the Milwaukee Water Council and the Wisconsin Economic Development Corp. announced The Global Freshwater Seed Accelerator (GFSA) that will focus on startups that address global challenges in freshwater. Six of the world's best early stage water technology startups will participate in the 6-month state-subsidized accelerator program for entrepreneurs. This program will be accommodated in the new Global Water Center. The center will also house water-related research facilities for universities, established water-related companies, start-up companies The Milwaukee Water Council wants to serve as a hub for water R&D activities. They have $83.5 million in public and private money budgeted over the next years to support water-related businesses and research. [92, 93, 94, 95]

[92] http://www.forbes.com/sites/joannmuller/2013/03/27/the-capital-of-water/
[93] http://www.thewateraccelerator.com/program-description.html
[94] http://www.thewatercouncil.com/global-water-center/
[95] http://www.thewatercouncil.com/about/membership/member-directory/

4.4 Northeast Ohio Water Technologies Cluster

NorTech, a regional nonprofit technology-based economic development organization, and a workgroup of industrial participants, researchers, economic development entities and government participants, developed a roadmap to form a new water technology cluster: the Northeast Ohio Water Technologies Cluster. The scope of this cluster is industrial water treatment and delivery, as well as storm water management (CSOs).

The goal of Nortech is to revitalize the region's economy, in emerging industries. Therefore, research is conducted to determine which assets (companies, universities, innovative capacity) the Cleveland region possess in emerging industries in relationship to the global demand. The strengths of the water technology sector in northeast Ohio are automation and controls, sorbents and water infrastructure corrosion protection.[96] Two examples of innovative companies within this cluster are ABS Materials and MAR Systems.[97] Their different versions of sorbents (Osorb™, Sorbster™) are capable of capturing different kinds of contaminants (e.g., oil, pesticides, metals and pharmaceutical products).[98]

In 2014 several accelerator water technology projects are planned to be started. These projects will speed up the commercialization process of certain technologies in order to start to generate revenue. The topics/technologies of the projects are not selected yet; however Nortech offers a large engagement program in order to help companies get faster to the market. Most important elements of this program are:

- Forming project team that supports the company (e.g., personal mentor, improving weaknesses);
- Help finding possibilities for financing and funding (e.g., risk capital network, looking for industry specific funds, non-dilutive funding);
- Find anchor clients and attach the companies or startups to credible customers (e.g., extra access to resources and support).

The Alliance for Water Future works together with NorTech in order to stimulate growth of innovative industrial water technologies.[99] The Alliance for Water Future is a cross-sector alliance in the Cleveland region, a neutral information provider. The foci of the Alliance are on public education and outreach, economic development, research and public policy. The partners include Nortech and MAR Systems, but also the Northeast Ohio Regional Sewer District.[100] Together the partners are working on solving region's water challenges, spurring innovative solutions for freshwater issues.

Storm water management is a major issue. Residents do not want to pay an extra fee that businesses already are paying. Green infrastructure implementation is potential solution. The City of Cleveland has a Sustainable Initiative which runs to 2019. Within this initiative the focus is also on water, with a Water Sustainability Council and 2015 as a celebration year of Clean Water.[101] The City of Cleveland wants to become a green and sustainable city, and in the field of water quality a lot of challenges have to be addressed.

4.5 Water Economy Network

In southwestern Pennsylvania businesses (e.g., CalgonCarbon, URS), academic (e.g., Carnegie Mellon University) and non-governmental organizations (e.g., Innovation Works) are linked together in the Water Economy Network (WEN) which was initiated by Sustainable Pittsburgh and the Pittsburgh Regional Alliance in September 2012. The formation of the Water Economy Network is the first step in building a

96 http://www.nortech.org/water#sectors
97 http://www.nortech.org/images/stories/about-us/Media_Kit/Water_Technologies_Roadmap_Fact_Sheet.pdf
98 http://www.absmaterials.com/osorb and http://www.marsystemsinc.com/ both Top 50 Water Tech Listing
99 http://forwaterfuture.org/
100 http://www.marsystemsinc.com/assets/attachments/file/AWF.pdf
101 http://www.sustainablecleveland.org/

water-related industry cluster in the greater Pittsburgh region and to become a water innovation hub in the United States.

The objective of WEN is to support regional water stakeholders to access new business opportunities, encourage new company formation through innovative technology development and deployment, and attract both national and international water-related industry.[102]

Challenges in this region that have to be addressed are related to:

- Major storm water overflows and capacity issues in cost effective ways;
- Maintaining water accessibility and quality in an aging infrastructure system;
- Creating the capacity to make smart water system more effectively to address maintenance, operation and investment challenges;
- Ensuring safe drinking and watershed protection while meeting the critical need to tap new sources of energy.[103]

Within the focus areas (e.g., water reuse and treatment, green and storm water infrastructure), projects are undertaken that can demonstrate innovative and sustainable solution to major regional water challenges. In 2012 eight projects were identified as potential projects for regional water innovation consortia.[104] Membrane filtration systems and UV treatments represent two areas of innovation in the Greater Pittsburgh region. Also, carbon nanotubes are being explored in desalination and other applications by Bayer MaterialScience, LLG in cooperation with the Pennsylvania NanoMaterials Commercialization Center.[105]

4.6 Green Jobs for Blue Water Initiative

The Green Jobs for Blue Water Initiative (GJBWI) was launched in 2009 by the Michigan Economic Development Corporation (MDEC). The goal is to establish a premier hub of water and wastewater technology and therefore this Michigan Water Technology Cluster focuses on becoming a center of excellence for the development, advancement and commercialization of needs-driven water technologies.

In Michigan there are approximately 400 companies active in the water sector.[106] Also, six water-related research centers and several universities with water and environmental programs are there. In 2008 Michigan signed a MOU with Israel and developed a strategic alliance with NewTech, Israel's Water Technologies Initiative.

By the end of 2009 the creation of a center of excellence with focus on municipal end-users was planned. In the period 2009-2010 multiple pilot and full-scale projects were started with Israeli and Michigan companies (e.g., Emefcy[107]). Also a legislative plan was developed to stimulate the innovative water technologies market in Michigan.[108]

Michigan is currently facing different water quality challenges in the Great Lakes. For instance, phosphorous is a growing concern for all the Great Lakes and inland lakes. It is causing algal mats, toxic algae, dead zones and other detrimental response in the lakes. Regulated point sources of phosphorous (e.g., wastewater treatment, urban storm water loading) have shown reductions of phosphorous loadings. For example, the Detroit Water and Sewerage Department's (DWSD) phosphorous discharge limit is now

102 http://watereconomynetwork.org/about-wen/
103 http://watereconomynetwork.org/wp-content/uploads/2012/09/WaterReport_January2011.pdf
104 http://watereconomynetwork.org/wp-content/uploads/2012/09/preliminary-water-matters-2.pdf
105 http://www.pananocenter.org/default.aspx
106 http://www.greenjobs4bluewaters.com/gj4bw/template1/pages/map.html
107 http://www.emefcy.com/
108 Presentation Gil Pezza, Water Technologies Initiative MEDC, May 2009

1.0 mg/L under normal dry-weather conditions. In the next NPDES permit of DWSD, tighter standards for the discharge of phosphorous will be included (goal is 0.5 mg/L).[109] However, for controlling unregulated non-point sources of phosphorous in the Great Lakes region (e.g., agricultural runoff), low-cost non-intrusive technologies are needed.

Another large issue in Michigan is sediment remediation and disposal. A vast amount of sediment is causing navigation, flooding, concerns, and environmental impairment. Because disposal options are limited in Michigan, sediment remediation is costly and the progress is slow. Therefore, there is a need for cost effective and environmentally friendly means of sediment remediation, reuse and disposal techniques for the surface waters.

Testing of *E. coli* cultures forms another challenge in Michigan and the Great Lakes region. *E. coli* measurements are the primary way of measuring sewage contamination in natural water sources and drinking water. However, detecting excrement from warm blooded animals (e.g., cattle, birds, squirrels, dogs and so forth) through testing *E. coli* cultures requires several hours and is not useful for most applications. A replacement for the *E. coli* test for quickly measuring human sewage as well as other feces would be welcomed by the industry.[110]

4.7 Massachusetts Water Innovation Initiative

During the presentation of the Environmental Protection Agency (EPA) at the AWWA ACE13 a map with water innovation clusters in the US was presented. The Massachusetts Water Innovation Initiative was mentioned as being in an early stage of development.

So far the water industry in Massachusetts is not widely known yet as an organized water technology cluster. The water industry in Massachusetts has published the Massachusetts Water Industry Market Map.[111]. Companies in MA include innovative multiple (more than 30) water start-ups (e.g., Oasys Water, Cambrian Innovation) product firms (e.g., Siemens, GE) and engineering firms (e.g., AECOM, CDM Smith). Examples of research and education are the Massachusetts Institute of Technology, Tufts, MREC and Boston University.

Areas of innovation covered by the water industry in MA are UV water treatment, forward osmosis, nutrient recovery, engineered membranes and nanoporous membranes. Water businesses in MA bring in over $4 billion in annual revenues. MA also signed a MoU with Israel.[112, 113, 114]

On June 19 2013 the Symposium on Water Innovation in Massachusetts was organized. During this symposium 160+ industry leaders of business, academia and governmental organizations from Massachusetts gathered to showcase cutting edge water technology and discuss how to make Massachusetts the hub for water innovation in the United States.[115] One of the proposals was to develop NEWin, New England Water Innovation Network. This should become a network of resources to test, pilot, and demonstrate new water technologies in order to attract companies and researchers to work and build businesses in MA, advance new technologies to local water issues and connect innovators to industry. NEWin's goal is to reduce or shorten the time and capital needed to come to commercial water

[109] http://www.greatlakes.org/document.doc?id=1247
[110] Gil Pezza, Water Technologies Initiative MEDC, via consul Chicago June 2013
[111] http://www.slideshare.net/dgoodtree/ma-water-industry-market-map
[112] http://www.xconomy.com/boston/2012/12/05/massachusetts-water-delegation-heading-to-israel-to-win-inbound-innovation/2/
[113] http://www.slideshare.net/dgoodtree/massachusetts-water-industry
[114] http://www.masscec.com/miip
[115] http://www.swim-ma.com/wp-content/uploads/2013/06/SWIM2013_WEB_Directory1.pdf

technology product. It will connect firms with laboratories and operating facilities, such as the state's Deer Island Sewage treatment plant, to more quickly prove and commercialize new technologies [116,117]

4.8 Living Laboratory Indianapolis

During Water 2.0 Event on May 15th 2013 of the Water Innovation Alliance, Erik Hromadka CEO of Global Water Technologies presented the concept of a Living Laboratory for Sustainability in Indianapolis, Indiana. Global Water Technologies is a small innovative company that identifies, develops and commercializes new non-chemical, filtration and other technologies to improve water efficiency.[118]

The development of this initiative is mainly driven by the aging water infrastructure problems in the US. In Indiana routinely more than 20 percent of drinking water is lost through an aging network of leaking underground pipes, most of them installed in the early to mid-1900s. Moreover, the water landscape is fragmented, with hundreds of drinking water systems across Indiana. The systems lack smart water grid technology to monitor conditions and identify problems.

Figure 6: RWELLS in Indianapolis.[102]

The living laboratory concept has been developed in partnership with several local companies (e.g., Peerless Pumps, a Grundfos company) and Indiana University Purdue University at Indianapolis (IUPUI), in order to deploy, test and refine new solutions in real-conditions. In that way smart water grid technologies can be created with better measurement, more efficient delivery and greater customer education on water use and conservation. An area north of IUPUI has been selected to become the Riverside Watershed Environmental Living Lab for Sustainability (RWELLS). In July 2013 three complementary smart technologies will be deployed and tested in RWELLS, for example the European patented sensors and software that measure pressure, flow and acoustic reading of the pipelines (WLM-SYSTEM[119]) will have their first US deployment in RWELLS.

[116] Presentation NEWin, 2013 the Symposium on Water Innovation,
[117] http://www.boston.com/business/innovation/blogs/inside-the-hive/2013/06/19/state-seeks-build-water-tech-cluster/P3IRbautmMTicTpUEqWUTJ/blog.html
[118] http://www.gwtr.com/about.php
[119] http://www.martinek.org/mwm/htm/en/WLM-SYSTEM.htm

Indiana overlaps two leading water technology clusters: Confluence (partner) and the Milwaukee Water Council. With this living laboratory concept Indiana aims to attract more businesses, water technology innovators, researchers, funding and public-private partnerships. The State of Indiana signed a MoU with Kentucky, Ohio to develop shared protocols for approval of new water technologies..[120,121]

4.9 The City of Philadelphia

In the past months the City of Philadelphia was mentioned during different interviews and presentations, as a city where a lot of water-related activities are employed. The city is known for her leading green initiatives and protection and enhancement of her watersheds by storm water management with green infrastructure. Already dozens of demonstration projects are installed in the city.[122, 123]

In 2012 the Philadelphia Water Department published her 25-year plan, "*Green City, Clean Waters"*, that committed the city to deploy the most comprehensive urban network of green infrastructure in the United States. More than 34 percent of the combined sewer area's (nearly 10,000 acres) will be improved to manage runoff on-site, relying mostly on green infrastructure for CSO reductions ($1.67 billion). Investments ($345 million) will be made for expanding sewage treatment plant capacity and increasing the transmission capacity of the combined sewer system. Another $420 million is budgeted to be spent on combinations of additional green and gray infrastructure improvements.[124,125] The City wants to become the "greenest city in the United States".[126] The EPA and the City of Philadelphia are currently discussing the creation of an innovative partnership to advance green storm water infrastructure for urban wet weather pollution control.

Philadelphia is also the first city in the US with a commercial scale geothermal system that provides building heat using domestic wastewater. This wastewater geothermal energy efficiency technology saves up to 60% in heating and cooling costs. The system combines a water source heat pump with a patented filtration device to transfer heat energy directly from sewage, using wastewater heat which is directly assessed from the adjacent sewage infrastructure. The City of Philadelphia wants to become a leader in resource recovery.[127]

Philadelphia has academic research centers that are important for the regional water technology sector. For instance, the Water and Environmental Technology (WET) Center at the Temple University is dedicated to research new cost-effective treatment technologies and optimization of existing operations at water and wastewater treatment plant. Recently, the Water Technology Innovation Ecosystem (Water-TIE) was established under direction of WET. The goal of WATER-Tie is to facility the identification, development and commercialization of innovative water treatment technologies that are relevant to the needs of industry and the environment.[128]

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[120] http://www.gwtr.com/smart_water_for_Indiana.pdf
[121] Global Water Technologies presentation, Erik Hromadka, Water 2.0 Event, May 15th 2013.
[122] http://www.phillywatersheds.org/youre-invited-phillys-first-porous-street
[123] http://phillywatersheds.org/biggreenmap
[124] http://watereconomynetwork.org/publication/rooftops-to-rivers-ii/wppa_open/ page 71-75.
[125] http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf
[126] www.phila.gov/green/greenworks/pdf/Greenworks_OnlinePDF_FINAL.pdf
[127] http://cityofphiladelphia.wordpress.com/2012/04/13/mayor-nutter-cuts-ribbon-on-wastewater-geothermal-heating-project/
[128] http://www.temple.edu/engineering/wet/water-tie

4.10 The State of Florida

During my interviews with water professionals and events, the state of Florida was mentioned several times as a state where water activities are undertaken. Initiatives are popping up to restructure or modernize the water infrastructure in order to address challenges with freshwater supply (e.g., salt water intrusion) and climate change (e.g., flood resistance). The 2013 Rising Seas Summit provided extra information about Florida's challenges with water and wastewater infrastructure and the effects of rising sea levels.

Water and wastewater infrastructure development in Florida receives attention from local, state and federal authorities. Recently, a consent decree between the EPA, the Florida Department of Environmental Protection and the Miami-Dade Water and Sewer Department (WASD) was signed. In the coming 15 years, $1.6 billion will be invested by WASD, the largest water and sewer utility in the southeastern US, to make improvements in the wastewater collection (e.g., sewers, pump stations) and the treatment (e.g., wastewater treatment facilities) system. These improvements are necessary because of the aging water and wastewater infrastructure that is causing leaks of treated drinking water and spills of raw waste into local waterways and the ambient environment.[129] Miami Beach is experiencing problems with aging infrastructure and is developing a storm water master plan to cope with events that occur once every 20, 50 or 100 years.

Rising sea levels cause infiltration of salt water in the sewer collection system. As a consequence, the salt water is affecting the treatment of municipal wastewater, making the treatment process less efficient and effective. Rebuilding concrete structures, elevating equipment (e.g., 1 foot above normal) and replacing pumping stations are examples of measures to improve resistance against flooding events. However implementing such improvements at the wastewater treatment facility at Virginia Key is very controversial because of the illogical location of the plant.[130]

40% of the residents in Florida live in Southeast Florida. The drinking water supply in this region is a huge challenge because the population is growing rapidly and fresh water supply depends on the Biscayne Aquifer. Water in this aquifer is coming from the Everglades ecosystem, including Lake Okeechobee. The Everglades are heavily affected by human interference (e.g., C&SF plan) and approximately 70% less water than several years ago flows through the ecosystem.[131]

The Southeast Florida Regional Compact for Climate Change was established by the State of Florida and counties in order to find solutions on a regional level for problems with salt intrusion, flooding events as a consequence of heavy rain and high tide or storms linked to drinking water and wastewater infrastructure. Solutions are needed at the short term because salt water is already pushing fresh water further landward, causing problems with water supply in the coastal areas. Because more fresh water sources are affected by salt water, alternative water sources are being explored in Florida. Reuse of wastewater (e.g., industrial), desalination (e.g., seawater or brackish water), aquifer recharge and coastal wetlands rehydration projects are undertaken. In order to address these challenges nationwide, the Water Utility Climate Alliance was established between public water and wastewater utilities and other agencies (e.g., Tampa Bay Water, New York City Department of Environmental Protection).[132] Another collaboration in Florida between water and sewer utilities is the Central Florida Water Initiative.[133]

[129] http://www.miamidade.gov/water/library/flyers/2013-capital-improvement-plan.pdf
[130] http://www.miamiherald.com/2012/12/02/3124200/miami-dade-proposes-spending-15.html
[131] http://www.evergladesplan.org/about/why_restore_pt_05.aspx
[132] http://www.wucaonline.org/html/about_us.html
[133] http://cfwiwater.com/

4.11 Case Study I: The Akron Water Initiative

In recent years, The City of Akron, Ohio is proactively forming science and technology bridges with different countries (e.g., Finland, Slovenia, and Israel) in several fields like energy, water and biopolymers. These "3 way" Technology Bridges are built on three key elements: 1) commercialization, 2) research and 3) resources. Based on these elements, foreign businesses are supported to enter the US market with their innovative products and technologies.[134, 135]

In their strategic plan 'The Akron Water Initiative', the City of Akron describes her goals to create bi-national innovative partnerships with several countries with leading global water technologies (e.g. The Netherlands). Akron wants to attract foreign innovative water technology companies to commercialize their products and technologies. The City of Akron is offering companies a soft landing pad, finding funding and helps them validate their technology for the US market. Because the City of Akron is the sole owner of different industry parks, a technology accelerator, an extensive water and wastewater system (e.g., reservoirs, pipelines, treatment plants) and several square miles of land, there are no long procedures regarding permits for establishing pilot tests sites in real-time situations.

The Greater Akron Region in Ohio is facing several water issues (see below and Appendix III) Therefore, the City of Akron is aiming for water technology companies (e.g., startup, small) who have potential solutions for these problems. Those companies preferably already sell products in other markets (e.g., Europe, Asia) and have the commitment for commercializing their products within 1-3 years after starting collaboration with Akron. There are short contact lines between the City, the University of Akron, Greater Akron Chamber of Commerce and Ohio EPA.

For instance, the Akron Global Business Accelerator (ABGA) is a program of the City of Akron. This business incubator is very successful (survival rate is 90%). The incubator, which is a member of Global Cleantech Cluster Association, offers established and small companies, as well as startups in the field of water technology and other sectors (e.g., manufacturing polymers, medical devices), the opportunity to develop and manufacture their product and technology for entrance at the US market. The real value is the management and consultation team. They assist in getting access to funding organizations, mentoring and monitoring, support with basic strategy modeling (e.g., identify gaps, create vision), strategic partnerships development (e.g., bring them in contact with the right people, leads, customers, complementary businesses).

The City of Akron is working hard to find solutions for their problems within the regulatory boundaries of the EPA, but is still <u>looking for assistance from abroad</u>. Regional water issues include:

- Disinfection byproducts control and unregulated emerging contaminants (e.g., pharmaceuticals, synthetic organic chemicals) which are driven by new EPA regulation and requirements. This will be the most important theme in the coming years, because EPA has resistance against emerging techniques for disinfection that are not proven yet. There is a need for innovative cost-effective advanced technologies for disinfection.
- Within Akron's watershed, biological pollutants (e.g., algae blooms and related toxins) are an important issue.[136] There is a need for innovative technologies for the detection, measurement, filtration and removal of these pollutants.
- Aging water infrastructure is a major issue. In order to address the infrastructure challenges the City of Akron earmarked about $100 million for water and sewer projects in 2013 and is planning

[134] http://www.ohio.com/business/agreement-brings-akron-slovenian-groups-together-for-job-creation-1.353149
[135] http://www.ohio.com/news/local/israeli-water-company-to-open-first-u-s-office-in-akron-1.266769
[136] http://www.ohio.com/news/concerns-over-toxic-algae-fester-1.184180

to assign $890 million for sewer upgrades in the coming 18 years.[137] Besides funding, new innovative and cost effective pipe (linings) replacements and repair technology, technology to identify and detect pipe weakness and corrosion, leak prediction and detection techniques and management and systems technologies are necessary to address the infrastructure problems.

- Process water or brine and waste treatment from horizontal fracturing in the Utica and Marcellus shale formations. Both the drilling process and well production produce liquid wastes. Only 10% of the used water in the process comes back up and can be reused. Until now the best way to deal with the waste water is deep well injection. In Ohio the volume of brines and other wastes from horizontal fracturing operations that have been disposed of in deep injection wells, has increased with almost 19% from 2011 till 2012.[138] Other ways to dispose the waste water are to dilute and to release it in rivers or streams. In order to obtain a permit discharge, mobile on-site treatment systems are needed that can cope with brine with high total dissolved solids (TDS) concentrations. Additional issues with horizontal fracturing are problems with radioactive muds and ground remediation.

The Midwest + Ontario region is a $4 trillion economy. Because the industry needs a lot of water for their production process, there are issues in wastewater and industrial water treatment. Many industries are relocating their manufacturing plant to the Midwest region because of the large freshwater source the Great Lakes contain 20% of the world's freshwater source. [139] Because of the Akron Water Initiative and the emerging issues, The Greater Akron region is offering interesting opportunities for water technology companies.

4.12 Case Study II: Maryland Environmental Service

The Maryland Environmental Service (MES) is a state agency in the State of Maryland, providing water and wastewater services at competitive rates to the government and private sector. Operating state owned treatment facilities is their main focus, in addition to consultancy services that are provided to private, industrial and public customers. MES operates and maintains 138 private, municipal and county plants, several shared-use facilities as well as 90 state-owned plants at correctional facilities, health facilities, rest areas and state parks.[140] MES' engineering group is working on capital improvements plans, selecting best technologies available for implementation on specific plants. In this way MES is able to keep up with the latest trends, technologies and practices in the wastewater industry

Because the state of Maryland is involved in the Chesapeake watershed protection, strict total nitrogen and phosphorous requirements apply. Treated wastewater needs to be in compliance with the discharge limits for total nitrogen and phosphorous when discharging wastewater in surface water (3-4 mg total nitrogen/L) and groundwater (10 mg total nitrogen /L).Wastewater treatment plants are designed to remove total nitrogen down to 3 ppm, phosphorous down to 2-3 ppm and to remove fecal and *E. coli.* Depending on the amount of fecal matter in the effluent, treated wastewater may be sprayed on land for infiltration to remove extra nitrogen and to serve as a buffer. Most of the treatment systems in Maryland are activated sludge systems with a 3, 4, or 5 stage nitrogen removal (e.g., anoxic zone, aerobic zone). In the US, deammonification (short cut nitrogen removal) is not widely used yet. Membranes in wastewater treatment are slowly becoming more applied in MD. The state funds updates of treatment plants in order to improve nitrogen removal.

137 http://www.water-technology.net/news/newsus-city-akron-earmarks-100m-to-develop-water-sewer-projects
138 http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/portage-county-is-no-1-in-ohio-for-injecting-drilling-wastes-1.413075
139 Received from Dr. C. Miller, University of Akron, July 2013.
140 http://www.menv.com/pages/waterwastewater/waterwastewater.html

Within Maryland there is a demand for decentralized small municipal wastewater systems that remove enough total nitrogen and phosphorous. MES is operating a lot of such decentralized septic tanks and onsite disposal systems that are not in compliance with the strict discharge limits. In the Clean Watersheds Needs Survey 2008 conducted by the EPA, the decentralized wastewater treatment systems needs in MD were between $1 and $5 billion.[141] These systems are used in approximately 20 percent of all homes in the United States. An estimated 10 to 20 percent of these systems malfunction each year, causing pollution to the environment and creating a risk to public health.[142] The required technology has to be able to remove total nitrogen to a level of 10 mg/l for discharging on groundwater and 3-4 mg/l for surface water. In MD discharging via groundwater is strictly regulated; normally septic tanks will treat wastewater only for solids and then drain it into a drain field underground where the water will be treated for nitrogen and phosphorous. This infiltrated treated wastewater will end up in the groundwater system and eventually in the surface water. A German company, pilot tested their mobile system to treat municipal sewage water: active biofilm in combination with ceramic membranes system with nanoparticles of alumoxide (low pore size, high pressure needed). Because of the ions presented in the water, as a result of a common polishing step (chloride), this technology did not work well.

In Maryland water reuse is getting more attention because groundwater reservoir levels are decreasing and more datacenters are established that need a lot of water for cooling. According to MES the recovery of nitrogen and phosphate is a trend in the US water technology market, but in MD such technologies are not widely applied yet. The removal of medicine residuals and pharmaceutical from wastewater and drinking water is an issue in MD as well. However, the main focus in coming years will be the removal of nutrients in order to improve the water quality of the Chesapeake Bay.

[141] http://water.epa.gov/scitech/datait/databases/cwns/upload/cwns2008rtc.pdf#page=33 blz. 72
[142] http://water.epa.gov/infrastructure/septic/

5. Opportunities in the US water technology sector

The previous chapters described the American water technology trends and focused on different water technology clusters and initiatives in the eastern part of the United States. This chapter will provide an overview of interesting opportunities for the Dutch water technology sector that were mentioned in the previous chapters. This chapter also includes a list of key trade events in the coming months that potentially offer opportunities for introduction in the US water technology market.

The water industry in the US is growing rapidly, offering opportunities in different sectors (e.g., equipment, (industrial) wastewater treatment). The Safe Drinking Water Act and the Clean Water Acts are the most important federal policy programs coordinated by the EPA. They provide treatment and discharge regulations, funding programs and a framework for operating and applying innovative water and wastewater treatment technologies.

5.1 The search for water technology solutions

The water technology trends showed the general needs for water technologies and equipment in the US. Based on chapter three the following technologies form opportunities for the Dutch water technology sector in the US water market:

- **Effective assessment and rehabilitation techniques** (paragraph 3.1)
    - e.g., leak detection, prediction models of condition systems, asset management models, downsizing;

New and more cost effective assessments (e.g., leak detection, prediction models of condition systems, asset management models) and rehabilitation techniques are needed. Increased emphasis should be placed on green infrastructure solutions for storm water management as well as on decentralized approaches (e.g., downsizing to small piping systems) that can reduce pumping and treatments costs.

- **Industrial water reuse technologies** (paragraph 3.2)
    - e.g., sewer mining, decentralized onsite treatment systems, MBR systems;

Water reuse and the use of reclaimed water are already applied widely in the US and are increasing. There is a significant need for technologies and approaches that foster substantially greater water reuse or sewer mining, and can reduce pollution and energy use. Utilities, municipalities and the industrial sector are seeking ways to implement environmentally friendly en economically feasible solutions to reserve water resources while meeting water demands.

- **Brine treatment techniques** (paragraph 3.3)
    - e.g., brine disposal, pretreatment optimization, energy conservation and overall productivity of membrane systems;

In the US the majority of the water treatment plants make use of membrane technology which is used both to convert seawater into drinking water as well as to treat brackish groundwater. The need for brine treatment is mostly driven by a shortage in available freshwater or when groundwater is threatened by salt intrusion. Challenges include brine disposal, pretreatment optimization, energy conservation and overall productivity of membrane systems. Significant barriers to implementing desalination technology in the United States are the uncertainty regarding how environmental impacts are addressed in the permitting processes and the long period of time it takes to implement a new technology.

- **Storm water management tools and green infrastructure techniques** (paragraph 3.4)
    - e.g., recharge basins, rapid infiltration beds, bioretention systems, storm water control mechanism, reducing total maximum daily loads;

An important issue in the American water technology sector is storm water management. Stricter federal and state regulations for wastewater and storm water systems are the main drivers for improving such systems. Threats for surface and groundwater quality are the combined sewer overflows and the sanitary sewer overflows, due to periods of heavy rainfall and aging wastewater management systems. There is a need for technologies that can address nonpoint sources of pollution, storm water control mechanisms and green infrastructure.

- **Nutrient recovery and removal techniques** (paragraph 3.5)
    - e.g., wastewater mining technologies, deammonification;

Nutrient recovery (e.g., wastewater mining) is expected to become an increasingly important topic in the United States in the coming years. Driven by the need to reduce nutrient pollution because of stricter regulations in surface water and drinking water supplies (caused by e.g., nitrogen, phosphorous), emerging technologies that can both treat and recover nutrients from water and wastewater will be needed in the United States. However, any new technology must be able to make the case that recovery and reuse of the materials or water is economically feasible.

- **Advanced disinfection techniques** (paragraph 3.6)
    - e.g., ultraviolet radiation systems, advanced oxidation, ozonation, electro chlorination, biological filtration;

In the US many utilities are considering changes to their treatment processes to avoid noncompliance issues with new disinfection byproduct (DBP) rules. A transition is visible in disinfection methods in the American drinking water sector; from only chlorine disinfection to upcoming ultraviolet radiation systems in combination with chloramines. Also advanced oxidation, ozonation, electro-chlorination, biological filtration and other disinfection methods are becoming more popular in the US. Until now disinfection has always been combined with chloramines or chlorine.

- **Smart water grid techniques** (paragraph 3.7)
    - e.g., smart water meters, electromagnetic and acoustic sensors, real-time communication channels, basic data management software, real-time data analytics and modeling software, automation and control tools;

Smart water networks are gaining traction in the US and efforts are made to implement smart water networks in the water industry. One of the problems is non-revenue water and improving system metering, data integrity, leak monitoring and control to improve system performance and reduce costs (e.g., costs for treating and pumping water). These efforts will also conserve precious water supplies. The main challenge of the utility with a smart water grid is how to cope with a flow of data *and* water. By making water systems smarter, utilities will be able to understand their buried assets, optimize their performance and life span, in the process making them more proactive instead of reactive.

- **Energy conservation and recovery techniques** (paragraph 3.8)
    - e.g., effective pumps, membranes, downsizing pipelines, geothermal energy, geo-exchange, sewer heat-recovery systems, thermal hydrolysis, biogas production;

In the US water and wastewater utilities uses significant amounts of electricity. Moreover, the electricity industry is the second largest user of water. Water reuse, climate change and the water & energy nexus are closely related. Turning water and wastewater facilities into net zero energy consumers or net producers of energy is the latest trend in the American water technology market. This change can be achieved by installing renewable energy technologies (e.g., geothermal energy, geo-exchange, and sewer heat-recovery systems) or by anaerobic digestion of sludge and other organic materials.

- **Techniques for monitoring and removal of emerging contaminants** (paragraph 3.9)
    - e.g., contaminants of emerging concern, hexavalent chromium, pharmaceuticals, nanomaterial.

Monitoring and removal of emerging contaminants, which are often unregulated, will be a trending topic in the US water technology market in the coming years. The EPA is also implementing new or stricter drinking water limits on numerous contaminants, including arsenic, radioactive contaminants, microbial and disinfection byproducts. CCL 3 is a list of contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations, but that are known or anticipated to occur in public water systems, and which may require regulation under the Safe Drinking Water Act (SDWA)

5.2 Water technological needs in the eastern US

Analyzing the several water technology clusters and initiatives gives insight where into the US certain water-related problems occur and what kind of water technologies are needed. Based on chapter 4 the following list provides an overview of the scopes of water activities and issues in the eastern part of the US:

- **Water technology clusters and initiatives are established to become an international water hub, developing and commercializing new and innovative technologies, and attracting business and universities;**
    - e.g., Confluence, Milwaukee, Michigan, Northeast Ohio, Massachusetts
- **Clusters and initiatives are looking for international collaboration;**
    - EPA Cincinnati researchers are seeking collaborations with external scientist and engineers to find solutions for wastewater, storm water, drinking water, water reuse and watershed management challenges
    - The Akron Water Initiative
- **The US water clusters and initiatives offer programs supporting companies with facilities like pilot test sites, accelerators, professional teams, funding aid, validating;**
    - Milwaukee Global Water Center
    - Indianapolis: Living laboratory for smart water grid technologies
    - Akron Accelerator
    - Massachusetts
- **Storm water management is a major issues for the clusters and initiatives;**
    - Northeast Ohio (Cleveland and Akron)
    - Michigan
    - The Greater Pittsburgh region
    - Philadelphia
- **Other major challenges in the different regions are:**
    - Water-related problems (e.g., brine disposal) caused by hydraulic fracturing (e.g., NE Ohio, Pennsylvania)

- Water quality challenges (e.g., nutrients, toxic algae) caused by non-point sources (e.g., Michigan, Philadelphia, Chesapeake Bay area)
- Aging water infrastructure (e.g., water accessibility and quality) and the renewal (e.g., Indianapolis. Ohio, The Greater Pittsburgh)
- Safe drinking and watershed protection (e.g., The Greater Pittsburgh, Florida)
- Flood resistance of water and wastewater infrastructure (e.g., Florida).

The strengths of the Dutch water technology sector are represented in the fields of sensor technology, membrane technology, decentralized approaches, industrial water reuse and effective nutrient removal and recovery. Also the Dutch water technology sector has a lot of experience with advanced disinfection techniques. Both the American and the Dutch water sectors have a lot in common regarding these issues and research themes.

5.3 Key water trade events

In the coming months several interesting water-related events and conferences will be organized internationally and in the United States. These events form key trade opportunities for the Dutch water technology sector in order to get into contact with American partners, companies and other water-related organizations.

In the period from September 2013 until June 2014 the following water-related conferences will be held in the United States:

- **The Annual Water & Environment Federation Technical Exhibition and Conference (WEFTEC);**[143]
  - WEFTEC 2013 in Chicago, Illinois; October 5 - 9 2013
  - With integrated event: WEF Storm water Congress
  - Latest developments in water quality and wastewater treatment technologies
- **Net Zero Cities;**[144]
  - Fort Collins, Colorado, October 23 - 24 2013
  - Focusing on net zero energy, carbon and water solutions
  - Water & Energy Nexus and Net Zero Water program
- **American Water Works Association (AWWA): The Water Quality Technology Conference and Exposition;**[145]
  - In Long Beach, California; November 3 - 7, 2013
  - Water quality and drinking water focus
- **AWWA WEF The Utility Management Conference;**[146]
  - Savannah, Georgia; February 25 - 28, 2014
  - Water and wastewater management topics
- **AWWA AMTA 2014 Membrane Technology Conference & Exposition;**[147]
  - Las Vegas, Nevada; March 10 - 13, 2014
  - Presenting latest developments in membrane water and wastewater treatment technologies (e.g., concentrate treatment, water reuse)
- **AWWA Sustainable Water Management Conference;**[148]
  - Denver, Colorado; March 30 - April 2 2014

[143] http://www.weftec.org/
[144] http://www.netzerocities.net/
[145] http://www.awwa.org/conferences-education/conferences/water-quality-technology.aspx
[146] http://wef.org/UtilityManagement2014/
[147] http://www.awwa.org/conferences-education/conferences/awwa-amta-membrane-technology.aspx
[148] http://www.awwa.org/conferences-education/conferences/sustainable-water-management.aspx

    - Presenting solutions water reuse, green infrastructure, management resources and infrastructure
- **AWWA Annual Conference & Exposition;**[149]
    - ACE14 in Boston, Massachusetts; June 8 - 12 2014
    - Latest developments in the water sector challenges

The Aquatech and the International Water Week (IWW) in Amsterdam are an excellent opportunity for American companies and clusters to meet the Dutch water technology sector. A lot of the Dutch water technology companies, universities and other organizations will be represented during this conference from November 4 - 8 2013. There will be a special focus on wastewater treatment and industrial water use.[150]

[149] http://www.awwa.org/conferences-education/conferences/annual-conference.aspx
[150] http://www.aquatechtrade.com/amsterdamen/Pages/default.aspx

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Appendix I: Glossary

In the text of the report specific water technology terms are used. This annex contains an alphabetic list of professional terms used in the water technology field that need more explanation in order to fully understand their meaning. With the help of the WateReuse and glossaries from other water-related reports, this glossary was established.

ADVANCED TREATMENT: Additional treatment provided to remove suspended and dissolved substances after conventional secondary treatment. Often this term is used to mean additional treatment after tertiary treatment for the purpose of further removing contaminants of concern to public health. This may include membrane filtration, reverse osmosis (RO), advanced oxidation, and disinfection with ultraviolet light (UV) and hydrogen peroxide (H_2O_2).

BRACKISH WATER: Water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than seawater.

CONSERVATION: Obtaining the benefits of water more efficiently, resulting in reduced demand for water. Sometimes called "end-use efficiency" or "demand management."

DIRECT INJECTION: Injecting recycled or reclaimed water through an injection well directly into a groundwater basin. If the water will later be used for drinking, the recycled water will receive advanced treatment prior to injection.

DISINFECTION: Water treatment which destroys potentially harmful bacteria, viruses, and protozoa by using chemicals (commonly chlorine, chloramine, or ozone) or a physical process (e.g., ultraviolet light).

EFFLUENT: The water leaving a water or wastewater treatment plant. If effluent has been treated to a high enough standard, it may be considered reclaimed or recycled.

ENDOCRINE DISRUPTING COMPOUNDS (EDCs): Chemicals that can interfere with the normal hormone function in humans and animals.

FILTRATION: A process that separates small particles from water by using a porous barrier to trap the particles and allowing the water through.

MAXIMUM CONTAMINANT LEVEL: The highest allowable amount of a constituent in water. Drinking water quality criteria are established by the US Environmental Protection Agency as regulatory standards.

MGD: Abbreviation for million gallons per day. This term is used to describe the volumes water treated and discharged from a treatment plant.

MICROFILTRATION: A physical separation process where tiny, hollow straw-like membranes separate particles from water. It is used as a pretreatment for reverse osmosis.

PATHOGENS: Disease-causing organisms (generally viruses, bacteria, protozoa, or fungi).

PRETREATMENT: A process in wastewater treatment where metal screens are used to remove large objects and chunks of debris.

PRIMARY TREATMENT: The first process in wastewater treatment where solid matter is removed

RECLAIMED WATER: Water that is used more than one time before it passes back into the natural water cycle. Wastewater that has been treated to a level that allows for its reuse for a beneficial purpose. Reclaimed water is sometimes another name for recycled water.

RECYCLED WATER: Water that is used more than one time before it passes back into the natural water cycle. Wastewater that has been treated to a level that allows for its reuse for a beneficial purpose. Recycled water is sometimes another name for reclaimed water.

REVERSE OSMOSIS: A method of removing salts or other impurities from water by forcing water through a semi-permeable membrane.

SALINITY: Generally, the concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids - TDS), electrical conductivity, or osmotic pressure. Where seawater is known to be the major source of salt, salinity is often used to refer to the concentration of chlorides in the water.

SEAWATER INTRUSION: The movement of salt water into a body of fresh water. It can occur in either surface water or groundwater basins.

SECONDARY TREATMENT: Treatment of wastewater to a nonpotable level so that it may be discharged into the natural hydrologic system. It is the minimum level of treatment that must be achieved for discharges from all municipal wastewater treatment facilities.

TERTIARY TREATMENT: Treatment of wastewater to a level beyond Secondary Treatment but below Potable.

ULTRAFILTRATION (UF): A membrane filtration process that falls between reverse osmosis (RO) and microfiltration (MF) in terms of the size of particles removed.

WASTEWATER: Water that has been previously used by a municipality, industry, or agriculture and has suffered a loss of quality as a result of use.

Appendix II: List of figures and tables

Figures:

Tables:

Appendix III: Emerging Water Issues in NE Ohio and the Midwest region

Emerging Water Issues in the US.

	Topics	Description	Technologies which could help resolve
Watershed	Raw Water Quality	Do to watershed run-off, the reservoirs are becoming more frequently susceptible to algal blooms. In some cases these algal blooms cause water treatment issues, can become toxic and cause taste and odor customer complaints.	A better way to identify algae is present and algae blooms are occurring. Currently staff has to perform periodic algae counts which are not continuous and are labor intensive. Also, their is no quick means to identify that the algae is producing taste, odor or toxins. These tests require outside labs and results takes several days. Finally, the use of algaecide is generally not an option because of new EPA rules, identifying a technology to kill algae without the addition of a chemical into the raw water would be beneficial. We are aware of sonic technology and UV technology which could work in the reservoirs.
	Raw Water Phosphorus Control	Phosphorus is a leading cause of organic activity in reservoirs which includes algae blooms. Treating high organic content raw water results in compromised drinking water quality including disinfection by products, additional chlorine demand, taste, odor, discoloration and toxins.	Finding a cost effective means to control and/or remove phosphorus from the raw water at a point more near its source before it promotes the organic activity in the reservoirs would be beneficial.
	Oil and Gas Drilling	Through the advancement of directional drilling technology, deep horizontal oil and gas wells are becoming the most productive means of extracting oil, gas and other valuable resources from thousands of feet beneath the surface. There are numerous steps involved with the process and each step can be improved to help insure environmental protection including site selection, the drilling operation, fracking, pre. and post well monitoring and wastewater management.	Finding the most environmentally friendly drilling processes, monitoring equipment for groundwater and surface water to help identify if well failure has occurred, subsurface groundwater mapping, environmentally friendly fracking fluids, alternatives to deep well injection of remaining frack fluid.
	Sedimentation of Raw Water Reservoirs	Akron's raw water reservoirs have accumulated sediment at their bottoms which results in anoxic (low dissolved oxygen) conditions which causes many treatment challenges.	Identifying new dredging technologies which can cost effectively remove these sediments without disrupting the water treatment process.
Water Treatment Plant	Treating Taste, Odor and Toxin issues	Typically powdered activated carbon is used to remove algae taste and odor causing compounds and toxins	Carbon treatment is costly and maintenance intensive when treating for a severe toxin, taste and/or odor events. Unique technologies to replace Carbon and remove these compounds would be beneficial.
	Disinfection by Product Control and Water Treatment	In 2012 a new Federal EPA Stage 2 DBP Rule went into effect and many systems are near or at violations levels. The University of Akron has done excellent work identifying the specific organic precursors to the DBP's utilizing fluorescence helping operators better determine the performance of treatment processes.	Identifying alternative oxidants which do not form DBP's as much as our existing chlorine dioxide, hypochlorite and potassium permanganate. Also, alternative coagulants.
	Unregulated contaminant Monitoring Rule (UCMR)	The EPA is requiring water utilities to sample for about 20 new emerging contaminants in 2013.	These contaminants are very unique and exotic and have become identifiable because of better monitoring technologies. Soon it is likely that treatment requirements will be established. Some of the contaminants include things such as pharmaceuticals, artificial chemicals, toxins, birth control, hormones, explosives, pesticides, etc....
	Advanced treatment for disinfection	New 2012 EPA Surface Water Treatment Rules demand better disinfection of cryptosporidium and giardia	There exists several Ultraviolet Light Technologies which are being considered at the Water Plant but because of the excessive costs and O&M demands these system are considered unfeasible. Interest in new and improved UV systems with reduced installation and O&M would be considered.
	Advanced Treatment for Turbidity (cloudiness of water) removal	New 2012 EPA Surface Water Treatment Rules demand better removal of turbidity. Like many other water plants, facilities continue to utilize 100 year sand filter technology to perform this task. Eventually advanced treatment will be required.	Akron is aware of several new technologies which would be classified as advanced treatment such as Membranes Filtration, Miex, Miox, but these are very capital and O&M intensive so finding more economically feasablie and effective advanced treatment systems would be valuable.

Distribution System	Disinfection by Products (DBP) in Distribution	In 2012 a new Federal EPA Stage 2 DBP Rule went into effect and many systems are near or at violations levels.	Improved technologies to clean and flush distribution tanks and pipes, Utilization of computer modeling programs to identify water age issues, Better design of distribution storage tanks with static and dynamic mixing, Remote in system Chlorine addition facilities, better advanced water treatment techniques, "smart" continuous in system bleeding techniques, managing distribution systems better to recognize distribution systems can cause DBP issues.
	Chlorine, PH, temperature, conductivity.	Most of EPA's continuous real time drinking quality rules are regulated at the point of entry into the water system. EPA rules are expanding and becoming more stringent requiring continuous real time information closer to the "Point of Use" within the distribution system. Historically for most utilities these samples are collected and analyzed by staff and they are not continuous, real time and become very labor intensive.	As these rules expand, the need for cost effective remote, real time sensors, with continuous monitoring is needed for these parameters instead of an analyst. These sensors must be low maintenance not requiring regular cleaning, calibration, and then would not only be used for regulatory compliance but can also be used to help optimize the water treatment process real time.
	Fluoride	In most Cities throughout the United States Fluoride addition is required for the purpose of dental health	The facilities at the water plant used to add fluoride (an acid) are always in very poor condition because of its acidic nature.
	Infrastructure Condition	Ageing Water Infrastructure is a major issue for Akron and most large Midwest water systems.	New cost effective water main inspection techniques that does not disrupt water service or stir up build-up on pipes, water main replacement technologies such as directional drilling and lining, alternative ideas to this huge capital problem for Akron and others is needed
	Emergency Water availability	As water systems get older the risk of failure (either quantity or Quality) of a water system becomes greater. In the event of these failures the quick access to supply customers with water to their homes is needed or the home, street and/or community would need to be evacuated.	Drinking Water Hauling, Water filling stations, Point of Use treatment, alternate supplies,
	Meter Reading Technologies	Advancements in meter reading technologies may be able to better serve the customer	Utilization of the meter to remotely perform turn on's and shut off's, troubleshoot, better communication methods, accuracy, etc...
Water System Wide	Instrumentation and Control	Because EPA rules has become more stringent and the level of staffing is reduced, reliance on the automation and control of most all water treatment systems is necessary.	SCADA Technologies which allow limited human interaction while continueing to insure optimal performance of the treatment processes warrant consideration. Currently multiple operating systems exist but we have struggled to make them all work together including SCADA, work order management, finance software, AVL, billing, Banner, etc....
Wastewater Collection	Inspection	Akron's proposed consent decree requires cleaning and televising of 20% of the collection system annually on sewers ranging in size from 6 inches to 120 inches. Some critical sewers cannot be taken out of service for televising and therefore need to be done with flow in the pipe. this is often performed with flotation devices and only captures video above the water surface.	This process could be improved if a video camera were developed that can be submerged, yet capture quality video to see the condition of the pipe interior below the water surface.
	Sampling and Metering	The master-metered communities are billed based on volume of wastewater discharged as well as the strength of that wastewater. The strength is generally determined based on suspended solids and biochemical oxygen demand. Samples of the wastewater from a community are obtained on a daily basis requiring labor to retrieve and analyze those samples.	An on-line analyzer that monitors wastewater quality/strength could minimize the labor required to obtain this information. No longer would it be necessary for manpower to visit these multiple sites, scattered about the fringes at the corporate limits where sewage from outlying communities flows into the City-owned collection system. The information could be telemeterd back to a "home-base" to provide real-time data that then would be the basis for the strength component of the billing.