Feasibility of Novel Leak Detection Technology in the Water Industry

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Executive Summary

Demand for water is expected to increase along with global population, putting pressure on industries that provide and consume the resource to do so more efficiently. One solution is to limit the water loss from leaking infrastructure. Water loss due to leaks exceeds 50 percent worldwide, and 15 percent in the U.S. As the price of water increases, the value of this leaking water will as well, financially incentivizing the employment of water loss solutions. This analysis explores the leak detection market opportunities for PFT Technology LLC and BaseTrace within the water industry.

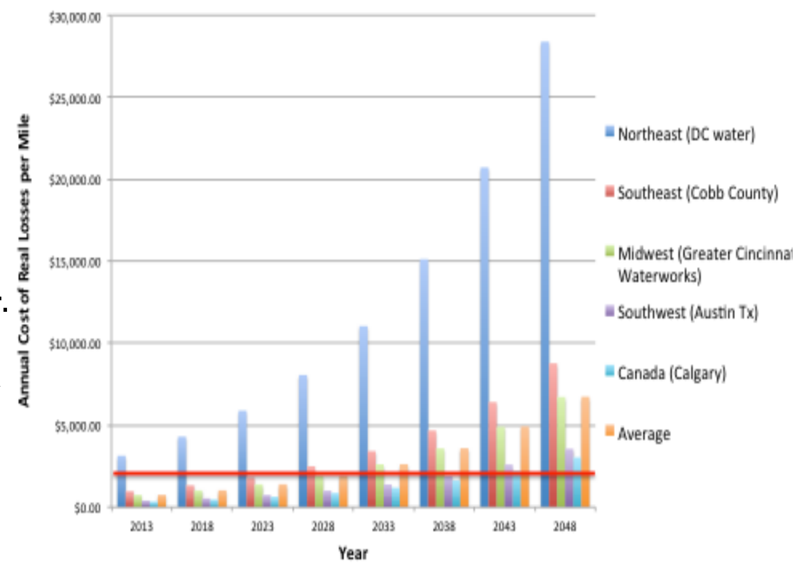
PFT Technology LLC and BaseTrace currently produce leak detection technology targeting the electric utility and hydro- fracturing industries respectively. The primary goal of this project was to identify water-related markets for these two companies to enter. This feasibility analysis is broken down into four sections: 1.) Industry Evaluation 2) Expert Interviews 3) Regulatory Analysis 4) Financial Modeling.

The primary market analyzed in this paper is the Water Supply market, but secondary markets explored include: Brownfields, Underground Storage Tanks, Irrigation, Stormwater Pipes, Dewatering Lines, and Nuclear Inleakage.

Overall, the Water Supply market proved to be an economically viable market for PFT to enter, while BaseTrace's technology would be more competitive in the Petroleum Brownfield Market. PFT's ability to trace leaks underground could generate large value in the Northeast, where repairing the old infrastructure in urban settings has proven to be costly. However, we believe their technology could potentially spread throughout the U.S as the value of water increases and their margins are met.

Recommendations

- PFT Technology should enter the Water Supply and Distribution markets regionally as price points are met according to the graph below. Price point is set at $2000/mile.



- In order to enter the market PFT must submit the product for health and safety testing.
- BaseTrace should further evaluate the economics of Petroleum Brownfields
- Both companies should further analyze competing technologies in the Nuclear Inleakage market to determine potential competitive advantages.

Introduction

The global human population is projected to increase by 2.5 billion by the year 2050, and the global demand for water is expected to grow concurrently at an annual rate of 3%, causing the number of people experiencing water shortage to double from approximately 2 to 4 billion by 2030. This, coupled with a worldwide water pipeline leakage rate of 50% will create massive social and environmental health issues if left unattended. This research project is conducted for two clients, PFT Technologies LLC and BaseTrace Inc. Both clients provide leak detection technology that can potentially address the growing issue of pipeline leakage.

The primary goal of this project is to conduct a feasibility analysis to determine whether or not it is in PFT Technology's best interest to target the water industry for their Perfluoro Carbon Tracer, and if so which specific market within the industry presents the best opportunity. PFT Technology LLC was formed in 2005 to provide leak location services for underground fluid filled cables in the utility industry. The tracer itself is a non-toxic dielectric fluid that has a unique signature in the atmosphere allowing it to be injected in small quantities and detected at just 4 parts per quadrillion. It has already entered the U.S market with customers including National Grid, U.S Power Generation, and Los Angeles Department of Water and Power.

Our secondary goal is to explore the market opportunities for tracers at a broader level as requested by BaseTrace. BaseTrace (our secondary client) produces a DNA-based tracer designed for tracing the fate of hydraulic fracturing fluids while giving each well a unique signature. They are a younger company still in the testing phase, and want to explore alternative markets for their technology. The markets this report explores for the entry of both technologies include: water utility supply lines, irrigation lines, stormwater pipes, wastewater lines, underground storage tanks, brownfields, and dewatering lines.

This project started with an extensive literature review to analyze target markets within the water industry. We provide each client with recommendations for which specific sector best fits their technology and how to best enter the market. Our project team interviewed a number of experts across the country for subjective analysis to gain insider information and opinion on the water industry and on how to best advise our clients. For PFT Tech, we went further and conducted a legal and regulatory analysis, as well as a financial analysis of price points and scenario analysis. We aim to identify potentially lucrative markets for our clients that will allow them to help improve on the looming water crisis.

Methods

We followed a multipronged approach to evaluate the water industry for our clients. This project began with an extensive literature review, market analysis, feasibility analysis, and culminated with recommendations for our clients on their next course of action.

Background and Market Analysis

This project involved looking at the water industry as a whole and determining a proper sector for potential entry by our clients. We conducted an extensive literature review over the vast spectrum of the water industry. This "big picture" approach allowed us to focus on certain sectors that appeared to potentially create value for the client, and expunge markets that did not apply to the product from a technological standpoint. Once target markets were selected, our team focused on these specific markets for a more focused analysis. An in-depth analysis of the chosen sectors was then undertaken by analyzing market data and qualitative factors such as regulations, competing technology, customer value proposition, and more.

Regulatory Analysis

We compiled an analysis of legal and regulatory issues that related to our clients' technology. The analysis consists of summaries of laws such as the Safe Drinking Water Act and RCRA, subjective analysis provided by either legal or professional experts, and overviews of EPA regulations and Congressional directives.

Expert Interviews

A customer and expert engagement package was devised to facilitate expert interviews. Ten experts with a range of knowledge across the water industry were interviewed over the phone and in person. Their answers were compiled and used for the subjective analysis portion of the project. All interview methods followed IRB standards and both team members received IRB certification and training.

Feasibility Analysis

The last analytical step used data obtained from a number of utilities and the American Water Works Association to quantify the value of water lost by leakage, and created market penetration curves for our companies based on price point research. The models analyze potential revenue and projected market penetration. All of the analytical steps were combined to create a final feasibility analysis and provide recommendations to our clients on where and how to best enter their product into the water industry.

Global Water Market

The global human population is projected to increase by 2.5 billion by the year 2050, and the global demand for water is expected to grow concurrently at an annual rate of 3%, causing the number of people experiencing water shortage to double from approximately 2 to 4 billion by 2030. Therefore, heavy investment in water infrastructure will be required to service those areas with increasing water demand. As populations grow, water scarcity is expected to rise, and the issues surrounding it will likely become more apparent.

The VDMA (German Engineering Association) estimates the volume (by revenue) of the water market in its entirety at USD $460-480 billion. This number does not include the vast amount of non-revenue water loss that is the focus of our research. This report is primarily focused on the United States water industry; however, potential opportunities for leak detection technology exist worldwide.

The U.S water and wastewater industry can be difficult to define and quantify, but it is typically estimated at about USD $130 billion per year.[1] There are approximately 55,000 water utilities and 16,000 wastewater utilities that are public agencies in the U.S, while 12 to 15 percent of people in the U.S receive their drinking water from private companies.[2] Overall, there is expected to be a slightly slower, but consistent growth of 5 to 7 percent a year for most businesses in the U.S water industry.[3]

Water Loss

Water loss due to leaks from pipelines exceeds 50% worldwide, leaving great opportunity for efficiency improvements in water infrastructure. The loss rate in the larger western European countries is between 20-30%, and is closer to 15% in the U.S. The World Bank estimates that 33 billion cubic meters of water are lost per year from urban areas of the world, and that the overall economic losses from non-revenue water (pipeline leaks and missed payments) total nearly 14 billion USD/year.[4] The need for technological advancement also exists at the back end of the water supply chain, where 80% of wastewater in developing countries "flows untreated into lakes, rivers, and streams"[5]. In China, this water contamination from leaking wastewater infrastructure has resulted in over 70% of the water in the country's rivers being of too poor quality for human consumption[6]. The water market as a whole is large-and growing, and we believe that plugging leaks in aging/defective infrastructure solves several of the existent problems described in this section.

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[1] Maxwell, Steve. "The Water Industry: A Closer Look at the Numbers." *American Water Works Association Journal* 103.5 (2011): 18-26. Web. 17 Nov. 2013.
[2] Maxwell, 20
[3] Maxwell, 24
[4] World Bank "The Challenge of Reducing Non-Revenue Water in Developing Countries". p. v.
[5] sic.
[6] DB World report, p 7. 2010

Water availability

Since the demand for water is expected to grow significantly, more pressure is being placed on suppliers to provide water. It is projected that by 2030 the demand for fresh water will exceed what is considered a sustainable supply by 40 percent[7], leaving suppliers with two choices: They can either allow the increasing amount of demand to drive the price upwards by fixing the supply at a certain sustainable amount, or begin tapping into other sources that may be more expensive to obtain/treat[8]. The first option brings up the ethical issues surrounding water supply, and the common debate of whether it is a commodity or human right, while the second option is the direction utilities will need to go in order to meet demand, but would also entail increases in the cost of water to the consumer. Plugging leaks in the water infrastructure could dampen the economic effects of having to supply more water by increasing the percentage of treated water that reaches the end user, thereby decreasing the total amount of water required.

Economic Restrictions

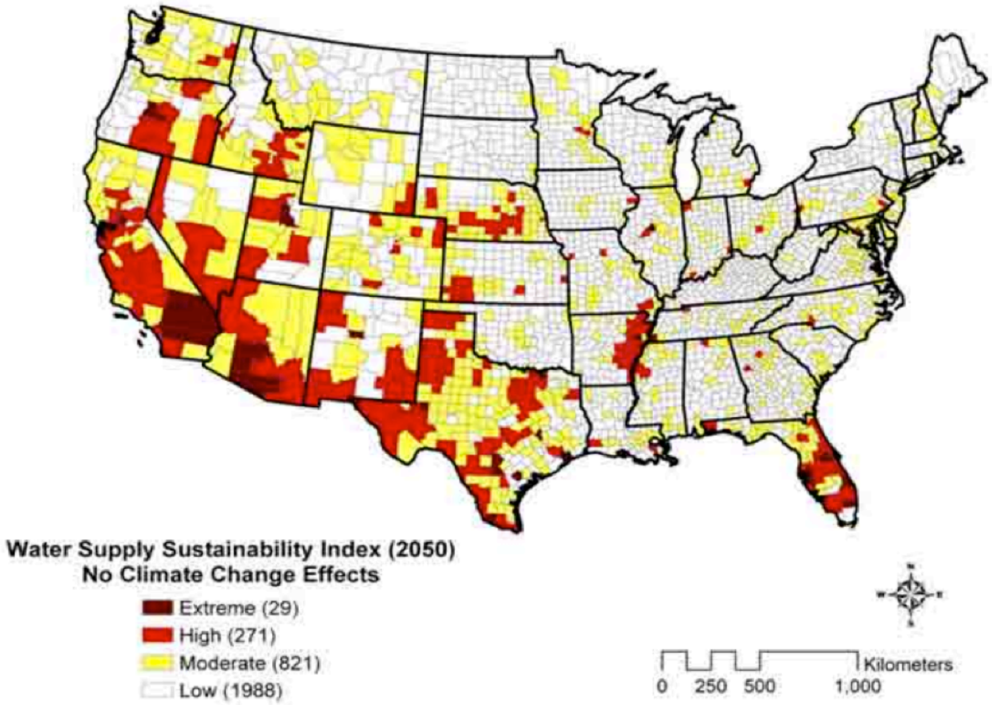
The combination of an increasing demand and a finite supply has tremendous economic implications for the water industry. Although the majority of the increase in global demand is expected to happen in the countries with rising middle classes such as China and India, the increase in natural gas production from hydraulic fracturing and other water-intensive practices is projected to increase usage in the United States as well. Increased use requires the installation of either new or larger infrastructure in many cases, which will require expensive capital improvement projects. In order to cover the capital costs of new infrastructure, utilities will have to charge more to the end users. Although public utility commissions try to limit increases in water prices, it will be difficult based on the margins water utilities operate at. Overall, the combination of increasing demand, finite supply, and the need to expand infrastructure is likely to cause a perpetual cycle of water price increases across the globe. As these prices become higher and the margins slimmer, efficiency measures will likely become more of a priority for water utilities as well as policy makers/regulators.

Climate Change and Drought

Climate change has proven to make droughts in the U.S. more severe and widespread, and is expected to exacerbate the shortage of U.S. water supply. The projected effects of climate change can be seen below in Figure 1:

7 EPA GAP Report

8 Global Water Security, p.1 2012



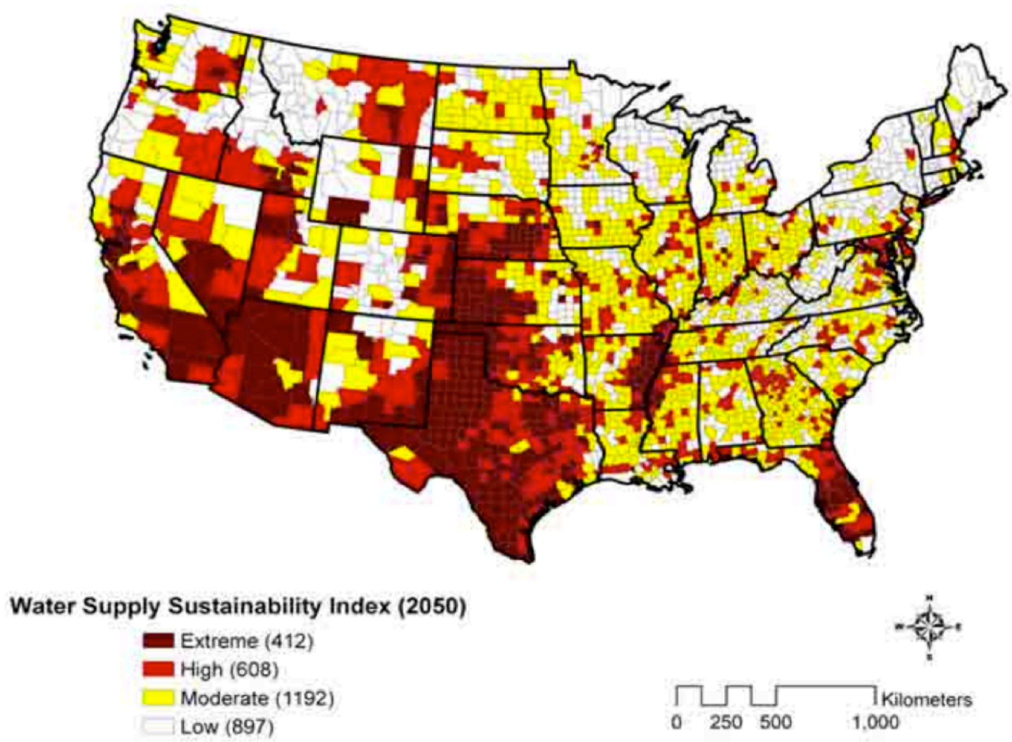


Figure 1: A projection of water supply in 2050 with no climate change effects is seen on the top, and water supply with climate change effects is found on the bottom. Climate change is expected to have very large effects on California, Texas, the southwest, and Montana's water supplies.

Operational and Maintenance Costs

One of the primary benefits of reducing the water loss caused by leaks (real losses) is the reduction in operational and maintenance costs. Beyond the obvious reduction in required supply, reducing the number of leaks would also decrease the electricity required to treat and pump water, reduce the damage and liability costs from disruptive piping failures, decrease the input rates of treatment chemicals, and reduce the required disinfectant dose.[9] If a leak detection technology can be priced at a level that these combined benefits outweigh the price of finding the leak and replacing the compromised piping, the technology should thrive.

Regulatory Requirements

Many utilities anticipate changes to the regulatory requirements surrounding water loss in the near future, although there are currently no national requirements. A number have states have therefore assumed responsibility and begun regulation and assessment of water loss in their systems. For example, Texas attempted to curb water loss by implementing House Bill 3338. This bill mandated bi-decadal water audits for public utilities starting in 2005. In 2009, the Pennsylvania Utility Commission (PUC), the Delaware River Basin Commission (DRBC), and the California Urban Water Conservation Council (CUWCC) required water utilities to implement annual water assessments by utilizing water audit software provided by the American Water Works Association (AWWA). The software focused on AWWA's stated four major types of water loss: real losses, distribution and customer service line leakage, customer metering inaccuracies, and accounting errors[10]. These values were obtained for several utilities and used for our calculations in the analysis section.

Public Service Responsibility

Fewer breaks in infrastructure can reduce the potential contamination of water and improve the reliability of the system as a whole. The environmental health risks associated with supplying water increases with the presence of leaks due to exposed pipes being potential entry points for microbial pathogens and other contaminants. Knowing that no leaks exist or that they will be managed facilitates the planning process in terms of how much new infrastructure needs to be built to serve a certain growth in demand.

[9] EPA "Control and Mitigation of Drinking Water Losses in Distribution Systems" p. 1-4.

[10] Sic.

Economic Level of Leakage

For the purposes of this project, one can think of leak detection as any method of locating a hole, break, or other compromised portion of a pipe. In the U.S where there is 880,000 miles of drinking water pipes, the AWWA estimates that there are close to 236,000 breaks per year leading to losses of approximately 2.8 billion USD in yearly revenue.[11] Lux research pegs the size of the worlds current annual market for inspection and repair technologies of water systems to be 20 billion USD and growing at a 10 percent rate. So the obvious question one may ask is: why isn't every leak being detected and fixed already?

The reason why many leaks are never fixed is due the fact that the non-revenue water losses can simply be passed onto end users, and from an economic standpoint some leaks are not worth fixing. Currently, many utilities include their estimated losses in the amount they charge the consumer per unit used. This leaves very little incentive for the utility to fix the leaks. From the utility standpoint it would cost them more money to fix the leak than to continue charging the end users. However, there is a point where the economic incentive shifts and plugging the leak makes economic sense. This incentive shifts because a utility can only charge the consumers up to the rate approved by the Public Utility Commission. As can be seen below in Figure 2[12], a parabolic cost curve is formed, demonstrating that not plugging enough leaks is economically irresponsible, and plugging too many leaks is also inefficient and costly. The optimal point, where the benefits of detecting and repairing leaks are maximized is known as the "Economic Level of Leakage"[13], or the ELL. Without the constraints of regulation, this is the extent to which a utility would want to capitalize on leak detection technology.

Several types of leak detection equipment are currently in use including acoustic leak detection surveys, electromagnetic field detection, thermal detection, chemical detection, smart metering, and tracer gases. Acoustic leak detection surveys are the most common form of active leakage control. These work by detecting the change in noise and pitch associated with water leaking from the pipe. Electromagnetic field detection is locates defective steel in concrete and pre-stressed pipelines. Thermal detection looks for contrasts in temperature in the ground surrounding a pipe. These are caused by lost water permeation into the soil. Chemical detection is used to discover contaminants that were added to the treated drinking water or wastewater that may not occur naturally. Smart meter leak location, which has received growing amounts of publicity lately, is the use of monitoring systems to locate leaks based on flow rates and quantity. Despite the recent hype about the "water smart grid," Brent Giles, who is a senior researcher at Lux believes that smart meters will only comprise about 20 percent of the market.[14]

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11 EPA "Control and Mitigation of Drinking Water Losses in Distribution Systems"

12 Sic.

13 Lux Water Intelligence Service "Plugging the Leaks: The Business of Water Infrastructure Repair"

14 Sic.

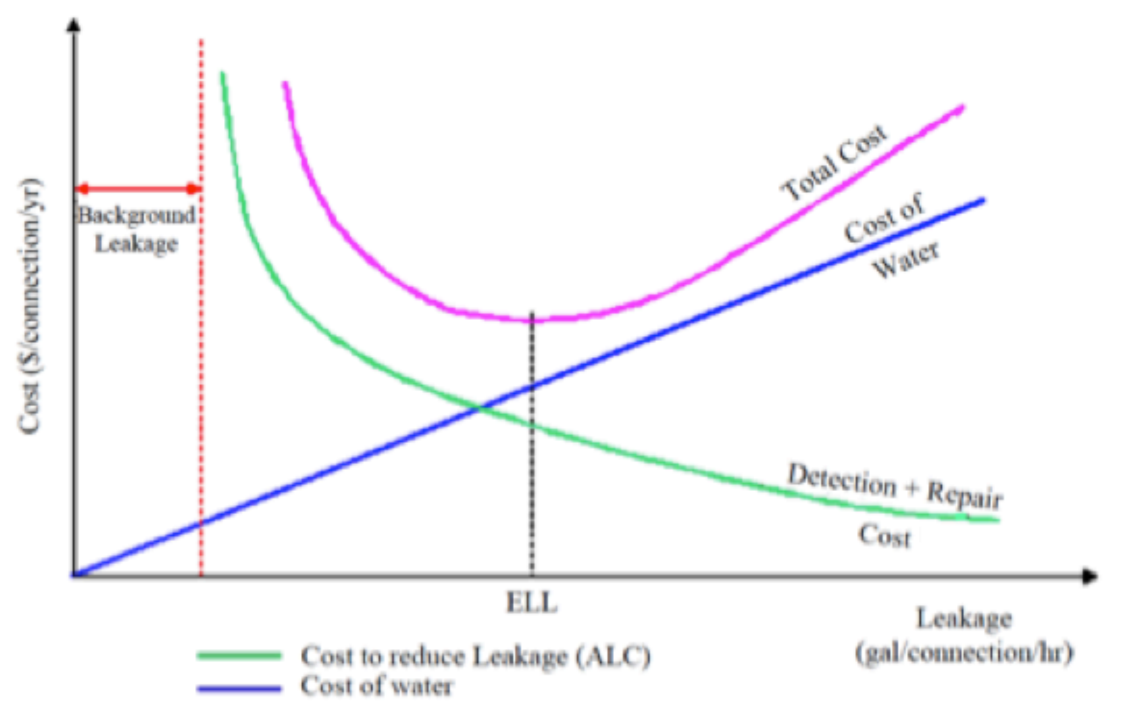

Figure 2: The sample ELL curve above shows the point where the detection frequency is best balanced with the amount of water loss from the system. The graph shows that it is economically logical to test for leaks up until a certain amount due to the reduced water loss, but it is not logical to test too often since the cost of detection and repair outweighs the economic benefit of reducing the minimal leakage.

Sector Analysis

The following section is a general overview of the findings related to leak detection technology in each of the specific sectors:

Water Utility Supply Lines

Since the supply side of water utilities tends to be where the value of water is calculated, it was the obvious starting point of our search. The main barrier to entry we believed that would exist was the regulations surrounding the injection of a chemical into a drinking water pipeline. However, after a thorough analysis of the safe drinking water act and current regulations we found that there are no current laws against the injection of Perfluoro Carbon tracers into drinking water. See Regulatory Analysis section.

Although there is no regulation preventing the injection of the tracer into water, there are some stigmas surrounding perflurocarbons in terms of health, which could act as a barrier to entry. Studies have found certain PFCs to be associated with endocrine disruption in women, causing the onset of early menopause.[15] Although the chemicals tested in these studies may not exhibit the same properties as PFT's tracer, and the doses administered in the tests are much higher than the amount that would reach the end user, PFT should be prepared to address this issue.

Irrigation

Agriculture is a major consumer of both ground and surface water in the U.S, and is responsible for approximately 37 percent of U.S freshwater withdrawals.[16] Irrigation systems tend to have several smaller leaks, which add up to significant losses. The EPA estimates that an irrigation system with a leak of 1/32nd of an inch in diameter can waste about 6,300 gallons of water per month.[17] Although several leaks of this size can add up to significant losses, the situation is similar to the background leaks in utility systems, where it would cost more to detect the several small leaks than to simply leave them alone. The adoption of more water efficient irrigation techniques, such as drip irrigation, also make this a less appealing market for PFT to enter.

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15 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3206400/

16 http://www.epa.gov/watersense/our_water/water_use_today.html

17 http://www.epa.gov/WaterSense/pubs/fixleak.html

Stormwater Pipes

Stormwater is defined as "rainwater and melted snow that runs off streets, lawns, and other sites"[18]. In rural areas stormwater run off drains into fluvial systems such as streams and rivers or is absorbed through soils to rejoin underground aquifers. However, this absorption does not occur with impermeable surfaces found in cities, such as pavement, so the water must be transported through storm drains in order to prevent flooding.[19] Traditional stormwater management focused on the collection of the water in pipes and transporting it directly to a stream or river, but recently the focus has shifted more towards smaller decentralized BMPs (Best management practices). Some of these include bioretention cells, grassed swales, infiltration trenches, permeable pavement, stormwater planters, and vegetated roofs.[20] The combination of this shift in practices and the lack of value put on stormwater make this a less viable market for PFT.

Underground Storage Tanks

Underground storage tanks can be divided into two types: suction piping and pressurized piping. The EPA lists the following occasions when no leak detection is needed for suction piping[21]:

1. The piping has enough slope so that the product in the pipe can drain back into the tank when suction is released.
2. The piping has only one check valve, which is as close as possible beneath the pump dispensing unit.

However, if the above requirements are not met, monthly monitoring must be done. Vapor monitoring is already a common practice for suction piping leak detection.

The other category of USTs is pressurized piping, which is required to have an automatic line leak detector and one other method of leak detection. Automatic line leak detectors sense changes in pressure and automatically shut off the line. PFT's tracer could potentially be used as the required secondary method of leak location. Some of the other secondary methods used include: interstitial monitoring, groundwater monitoring, statistical inventory reconciliation, or an annual tightness test. Both types of USTs described in this section are required to perform line tightness tests at certain annual intervals.

Line tightness tests are comprised of a specific line being removed from service and pressurized. A pressure drop over time suggests the presence of a leak. PFTs tracer could potentially be used at this point in the process to determine the exact location of the leak.[22]

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[18] IIT Bombay, "Techfest – Yojna" www.techfest.org

[19] http://www.epa.gov/greeningepa/stormwater/

[20] http://www.epa.gov/oaintrnt/stormwater/best_practices.htm

[21] http://www.epa.gov/oust/pubs/Stot05_Rev4-6-09.pdf

[22] http://www.epa.gov/oust/ustsystm/leakpipe.htm

Brownfields

The federal government defines brownfields as "abandoned, idle, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination."[23] They are often the sites of old factories or other businesses and some of the dangers include debris, dilapidated buildings, toxic chemicals, and rusty nails and pipes. A general 4-step process of brownfield redevelopment is provided by Brown University and can be found below:

1. Brownfields are identified by the local city or state
2. If the brownfield fits the EPA definition, they are eligible to receive federal and/or state funding for environmental sampling.
3. After the assessment is complete, a plan for cleaning the site is formed and presented to the public.
4. Once funding sources have been identified, the site is developed. [24]

The Rhode Island Department of Environmental Management (RIDEM) also plays a large role in the cleanup process. RIDEM strives to limit hazardous chemicals or petroleum leaks from USTs. They are in charge of performing tests to determine the extent of contamination and may be an entry point for PFT's tracer.

There are more than 450,000 brownfields in the U.S, and it has been shown that reinvesting in these properties "increases local tax bases, facilitates job growth, utilizes existing infrastructure, takes development pressures off of undeveloped land, and protects the environment." [25] The National Brownfield Association estimates that 2 trillion USD of real estate is devalued due to the presence of environmental hazards; so cleaning up these sites could prevent those losses.[26] A study of 48 redevelopment projects in 12 cities and 4 states concluded that immediate cleanup costs are the main deterrent to inner-city redevelopment.[27] Therefore, the price of brownfields has dropped, leading to very low market clearing prices to compensate for the risk associated with purchasing the land. However, as populations grow and undeveloped land becomes scarcer the value of these projects will most likely increase, causing the market to grow. Most of these projects are eligible to receive funding through the EPA, HUD (Housing and Urban Development), and EDA (Economic Development Administration), and public-private partnerships are becoming more common.[28]

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[23] http://www.brownfieldscenter.org/big/bfbasics.shtml
[24] http://www.brown.edu/Research/EnvStudies_Theses/summit/Briefing_Papers/Brownfields/

[25] http://www.epa.gov/brownfields/basic_info.htm
[26] http://www.epa.gov/osw/hazard/correctiveaction/curriculum/download/brown.pdf
[27] http://www.huduser.org/publications/econdev/bfield.html
[28] http://www.epa.gov/oust/petroleumbrownfields/pbpartner.htm

The niche market that appears to be the most viable for PFTs tracer is petroleum brownfields. Of the 450,000 brownfield sites in the U.S, about one half are thought to be impacted by petroleum from leaking USTs at old gas stations.[29] These sites tend to be prioritized in terms of cleanup since the petroleum can potentially contaminate groundwater. Therefore, the funding issues associated with other brownfields are mitigated to a degree. Further research quantifying the value of cleaning up and repurposing the land will be important in determining the potential of this market for PFT and BaseTrace's technologies.

Dewatering Lines

Dewatering is the removal of draining groundwater or surface water from a riverbed, construction site, caisson, or mineshaft by pumping or evaporation. Dewatering is done because it is illegal to discharge any water containing sediments or contaminants.[30] The typical projects that require dewatering, according to the San Jose Environmental Services Department are: "new construction, foundation work, utilities infrastructure installation and repair, electrical conduits, vaults, sewer line and storm drain maintenance, and phone lines and cable TV installation and repair."[31] The way the process works is the party hoping to dewater from a site must contact the Regional Water Quality Control Plant (RWQCP) and ask if the groundwater needs to be tested. Based on site history the RWQCP will determine if the water must be tested. Depending on the results, the group has three discharge options. If sediments are not present, discharge to the storm drain system will be allowed. In some contaminant load situations, discharge may be limited to a sanitary sewer. In rare cases, the group may be required to transport groundwater to a special off-site treatment plant. The size and length of these projects vary greatly, making this a difficult market to assess. Most of the pipes operate temporarily until the project is completed, making the use of tracers in this industry unlikely and infrequent.[32]

Nuclear

In nuclear plants, tracer gases are being used to measure inleakage and condenser leakage. Inleakage is when untreated air enters a plant. Inleakage is an issue because air traveling into the plant can alter the temperature, making it less safe.[33] Condenser leakage is when air or water leaks into the condenser. This is an issue because it can cause disk cracking and increase the level of dissolved oxygen in the

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[29] http://www.epa.gov/oust/petroleumbrownfields/pbbasic.htm

[30] Dewatering from Construction Sites and In-Ground Utilities Maintenance. San Jose Environmental Services Department

[31] sic.

[32] Sic.

[33] Control Room Inleakage Measurements Using Tracer Gas Techniques. https://www.aiha.org/aihce06/handouts/b3lagus.pdf

feedwater.[34] Condenser leakage is estimated to cause a 3.8% annual loss in nuclear plants.[35] Currently, sulfur hexafluoride (SF_6) and helium are used to trace condenser leakage. The primary advantage of SF_6 in this market is that it can be tested at low quantities (one part per 10 billion parts air).[36] Since this aligns with the competitive advantages of PFT's tracer, we believe it could be a viable market. However, since competing technologies already exist, PFT's tracer should be performance tested alongside these established products.

Summary

The initial sector analysis study identified ideal areas for our clients to begin product implementation. The irrigation, stormwater pipeline, and dewatering line sectors were removed from further consideration after the analysis step. The underground storage tanks, brownfields, and nuclear industries were determined to be potentially economically viable for our clients if certain barriers to entry can be overcome. The strongest sector appears to be the drinking water utility supply market. This area appears to have the most potential for our clients' leak detection technology and is explored in much greater detail in the rest of this analysis.

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34 https://www.concosystems.com/sites/default/files/userfiles/files/techical-papers/condenser-leak-detection-using-sf6-tracer-gas-technical-brief.pdf

35 https://www.concosystems.com/sites/default/files/userfiles/files/techical-papers/condenser-leak-detection-using-sf6-tracer-gas-technical-brief.pdf

36 https://www.concosystems.com/sites/default/files/userfiles/files/techical-papers/condenser-leak-detection-using-sf6-tracer-gas-technical-brief.pdf

Expert Interviews

This project incorporates the expertise of ten water industry experts in its feasibility analysis. Experts were interviewed by the project team and come from many different sectors, including public and private utilities, policy, consulting, regulatory, legal, and academia. Both team members are Institutional Review Board (IRB) certified and followed IRB standards during interviews. A general interview form, along with summaries of all interviews, may be found in the Appendix. This section describes the general trends and expert opinions derived from the interview

Subjective Analysis

All the experts interviewed seemed generally optimistic that there is a market for leak detection tracers, but some warned that the road to product adaption would not be easy. One of the biggest barriers to implementing new leak detection technology is that the United States as a whole is fairly indifferent to lost water. Public utilities have little incentive to get leak percentage lower than the national average because the cost of water in most areas is artificially low and leaks are "baked in" to their rate structure. Private utilities present an opportunity, because although their losses are also "baked in" to their rate structure, any saved money will count towards their bottom line. This will be especially important in areas that are experiencing water scarcity, such as the Southwest, or other parts of the world, such as the Middle East.

Almost all utilities have leak detection technology in place already. Most use acoustic sensors or advanced metering systems. At the current cost of water, most experts have deemed these systems "good enough". However, some utilities experience much higher rates of water loss (30-40%) and may be amenable to implementing new technologies, given the techniques are cost effective.

All experts agree with existing projections that water scarcity will increase over the following decades, as population growth, increased energy and agricultural production, and climate change will increase demand for water. At some point in the near future, all interviewed experts expressed a belief that countries and utilities will have to start charging the "real price" of water. When this occurs, the market will be more interested in conservation of water and water loss through leakage will become increasingly important. Two of the experts interviewed mentioned observing this growing desire already. This will create an opportunity for technological innovation and decrease barriers posed by traditional leak detection methods.

Another concern with waterborne tracers is the ability to put the tracer safely into drinking water. All experts from utilities mentioned that any chemical product would have to be safe and approved by EPA or state government before they would consider using it. Some experts pointed to the aforementioned high-water loss systems as potential candidates for trial runs. As we will discuss later in the paper, we have begun talks with potential large scale candidates who may be interested in testing the chemicals for safety and implementation.

One expert suggested that the manner in which the product is pitched will be crucial to the success of the product. The sale should revolve around more than savings on leak detection. He suggested approaching the issue as an investment in maintaining the pipeline lifetime. An investment in a technology that will improve leak detection will allow a company to extend the life of their pipes by ten or fifteen years, delaying capital expenditures, and thus creating a large value proposition for the company.

The general consensus is that private utilities will be the most willing to implement our client's products. Private utilities are not expected to rise above a 20% total market share, but this is still a massive market.

In conclusion, our experts were cautiously optimistic about our clients' products having success in this market. There are limited opportunities today, at least in the United States, based on the low cost for water and the relatively low effects of water scarcity. Some areas of the country, and some utilities experience much higher costs of water, water scarcity, and pipeline leakage. These will be good targets at this time. As water scarcity continues to become a bigger issue, more and more companies will begin to care about pipeline loss, and this may very well become a valuable proposition over the next 2 decades. Most companies in the water sector are risk averse and happy with current leak detection technology, but this is again contingent on cost of water. The experts suggest finding a niche market in the areas that are hit the hardest, and use this as a starting point to implement the technology. All remained optimistic that the market for detection technology will grow in the future, as water use issues intensify.

Regulatory Analysis

This section constitutes a brief summary of our legal and regulatory analysis of the implementation of PFT Technology's perfluoro carbon tracer in the drinking water industry. A detailed legal and regulatory analysis may be found in the Appendix. Our research outlines major federal laws and regulations pertaining to drinking water, such as the Safe Drinking Water Act (SDWA), Toxic Substances Control Act (TSCA), and the Underground Injection Program (UIP). This section also outlines the general process of introducing a chemical into drinking water at the state level. Our research shows no major legal restrictions regarding the placement of perflourocarbon tracers into drinking water. However, subjective analysis and expert interviews suggest that there may be policy hurdles to overcome due to the negative reputation of chemicals with the "per" prefix, as well as the generally risk averse nature of the industry when introducing new chemicals into regulated potable water.

Although there are no technically legal restrictions surrounding the use of our clients' tracers in drinking water, there are some key issues to be addressed. The SDWA gives the EPA the authority to regulate the over 160,000 water systems across the US. Much of this responsibility is handed down to the states however. If a new chemical is not on the EPA's list for contaminants, the EPA must conduct a risk assessment study and cost benefit analysis before it can be implemented. At the state level, permitting must be acquired from the Department of Water Resources before it is used in the drinking water. Here the potential contaminant is tested and modeled extensively before a decision is made. This is nothing new, as new chemicals are added and concentrations of existing chemicals are changed with some regularity.

Fluoride

The EPA recently conducted a risk assessment of fluoride levels in drinking water. This was in response to recommendations by the National Research Council that the EPA review and update the Fluoride control standards[37]. Perflourocarbons are at their base Carbon chains saturated with Flouride. The EPA has set a Maximum Contaminant Level for Fluoride at 4.0 mg/L, with a secondary standard (non-enforceable) set at 2 mg/L. The agency concluded that some children are likely exposed to too much fluoride "at least occasionally[38]." This has not caused the EPA to make a decision about placing additional regulations on fluoride or fluoride-containing compounds. The EPA is currently conducting a new risk assessment to determine whether or not they should revise the drinking water standard.

[37] NRC "Flouride in Drinking Water: A Scientific Review of EPA's standards."
[38] Sic.

Results

We were able to monetarily quantify the value of water losses for a subset of 26 utilities throughout the U.S by utilizing 2012 validated water audit data from the AWWA Water Loss Control Committee. The AWWA defines real losses as the "annual volumes lost through all types of leaks, breaks and overflows on mains, service reservoirs and service connections up to the point of customer metering."[39] Although by definition real losses include more than just leaks, for our purposes we assumed that the values reported for real losses were indicative of the leakage, meaning that we deemed the amount of overflow negligible. The preliminary results demonstrating the real losses for our set of 26 utilities can be found in Figure 3.

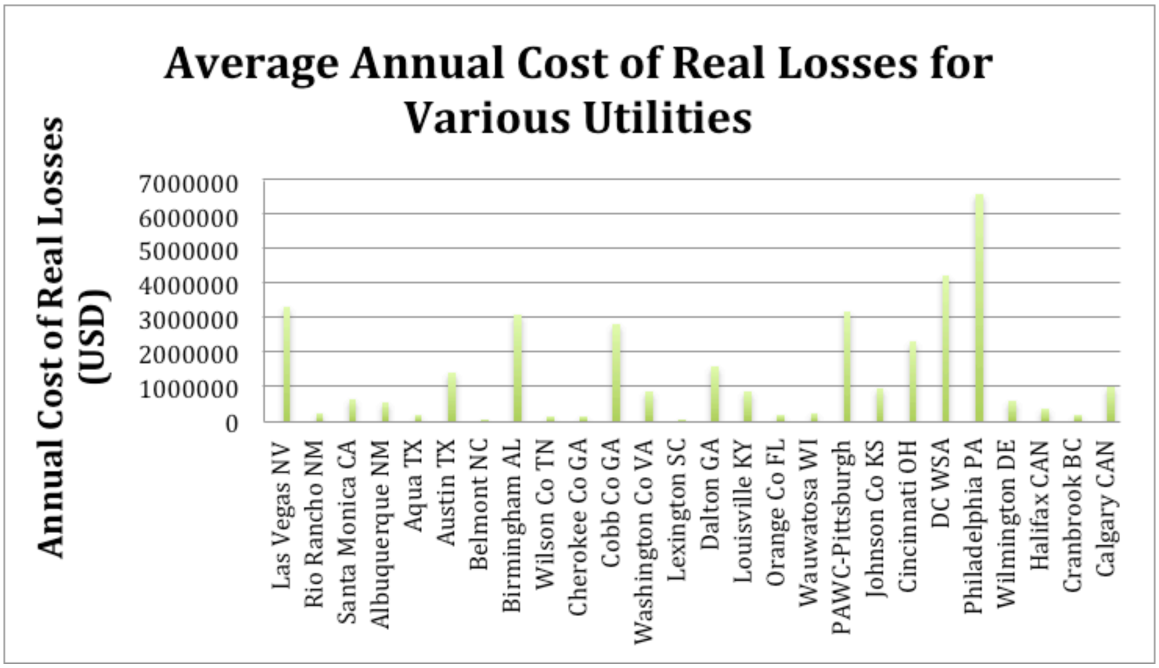

Figure 3: The above figure shows the annual cost of real losses for various utilities. As one can see, Philadelphia, Washington DC, and Las Vegas had the highest costs.

Based on our data, we became curious if there were significant regional differences in the amount of money lost due to leaks, so we clustered the utilities into 5 regions: Southwest, Southeast, Midwest, Northeast, and Canada. A breakdown of how the utilities were categorized can be found on the following page in Table 1.

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39 http://www.epa.gov/safewater/pws/pdfs/analysis_wa-03_water_loss_doc_final_draft_v62.pdfhttp://www.awwa.org/Portals/0/files/resources/water%20knowledge/water%20loss%20control/iwa-awwa-method-awwa.pdf

Table 1: Breakdown of how each of the utilities was categorized by region. The utilities are listed by their location.

Southwest	Southeast	Midwest	Northeast	Canada
Las Vegas NV	Belmont NC	Wauwatosa WI	Washington DC	Halifax CAN
Rio Rancho NM	Birmingham AL	PAWC-Pittsburgh PA	Philidelphia PA	Cranbrook BC
Santa Monica CA	Wilson Co TN	Johnson Co KS	Wilmington DE	Calgary CAN
Albuquerque NM	Cherokee Co GA	Cincinnati OH		
Aqua TX	Cobb Co GA			
Austin TX	Washington Co VA			
	Lexington SC			
	Dalton GA			
	Louisville KY			
	Orange Co FL			

Next, we calculated the average annual cost of real losses for each of the regions and plotted them in Figure 4:

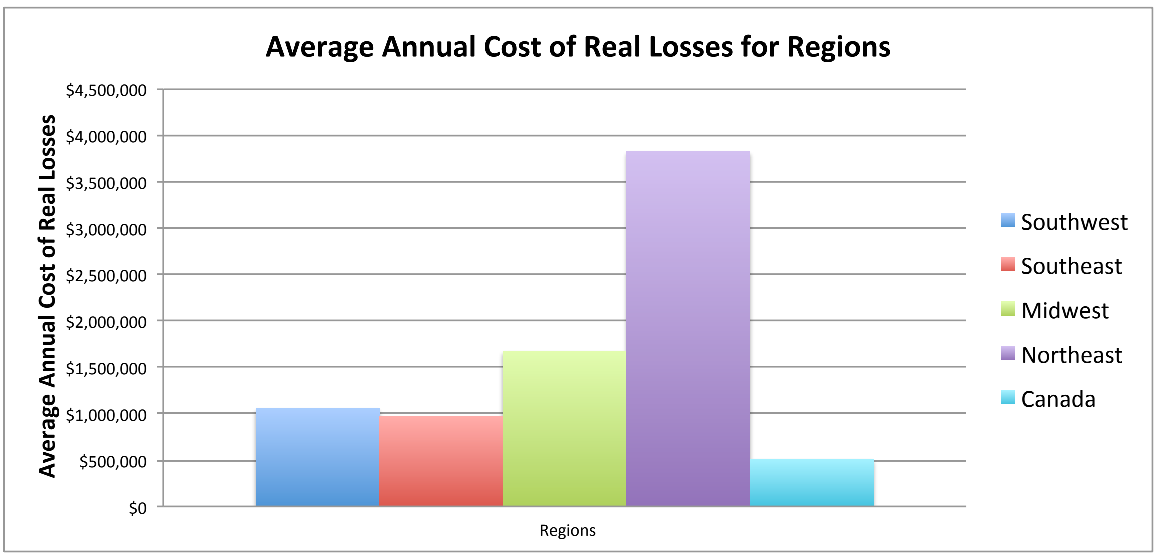

Figure 4: The average annual cost of the real losses for several regions in the U.S. and Canada

As the above graph shows, the annual cost of real losses for the Northeast was found to be significantly higher than the other regions. This was unsurprising considering that the northeast tends to have older water systems and infrastructure, and the utilities tend to serve a much larger population. Therefore, the overall costs tend to be much higher as well.

Although the northeast had the highest average costs of real losses, the fact that their overall costs were higher as well made us question the significance of real losses within each of the utility's systems. We calculated the real losses as a percent of total cost for each of the utilities, and then categorized them regionally to test this, which can be seen in Figure 5.

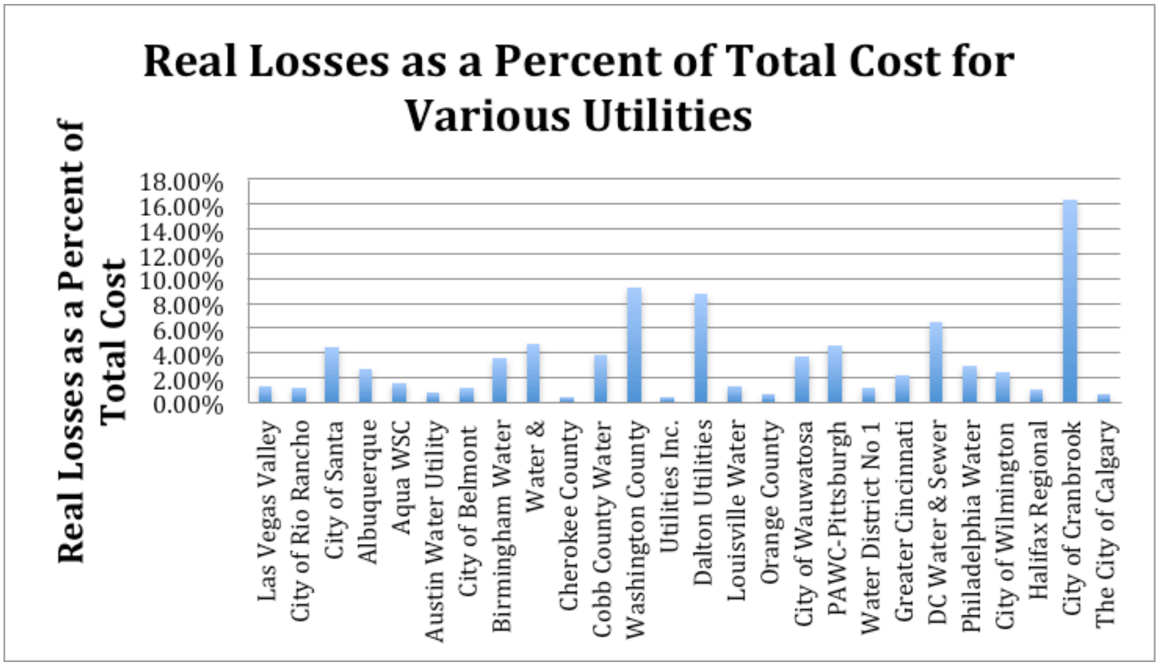

Figure 5: Real losses as a percent of total cost for the 26 utilities analyzed for the preliminary results section. The average of the real losses as a percent of the total cost was found to be 3.36% or 0.0336.

Using the categorization found in Table 1, we then plotted the average real losses as a percent of total cost for the 5 regions. This was done in order to determine the financial significance of leaks and whether or not they comprise a large enough portion of utilities total costs to warrant using our client's technology. The results of these calculations can be seen in Figure 6 on the following page.

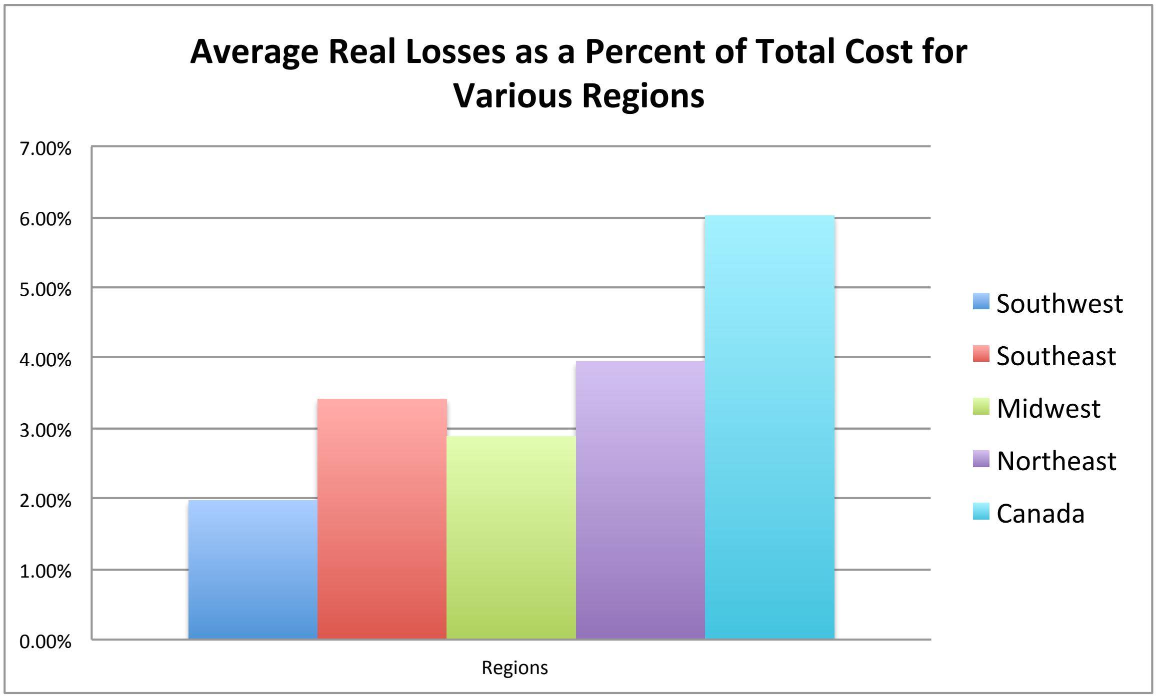

Figure 6: Regional breakdown of the percent of total cost made up by real losses.

Figure 6 shows that the leaks in the northeast comprise a significant percentage of the utilities' total annual cost. The average for all of the regions was calculated to be 3.65%, and the northeast had an average of 3.95%. Therefore, utilities may prioritize leak detection and repair in this region since it comprises a significant portion of their costs. However, PFT should calculate and present a long term NPV of leak detection and repair to these utilities to better demonstrate the value of pursuing leak detection projects in case other capital improvement projects account for a larger percentage of a utility's cost.

In order to further relate these values to PFT's tracer we calculated the projected annual cost of real losses per mile through 2050. We believed this would allow PFT to identify both when and where they should enter the market based on their price points. Within each graph a low, medium, and high scenario was plotted based on 2,6.5, and 8 percent annual increases respectively. The medium scenario value is based on the average annual rate increase numbers for the country over the last 13 years as reported by the New York City Water Board.[40] The 2013 starting data point is based on the data given by the AWWA 2012 Validated Water Audit Data. The corresponding data can be found in the appendix.

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[40] New York City Water Board: Public Information Regarding Water and Wastewater Rates p. 10. April 2012.

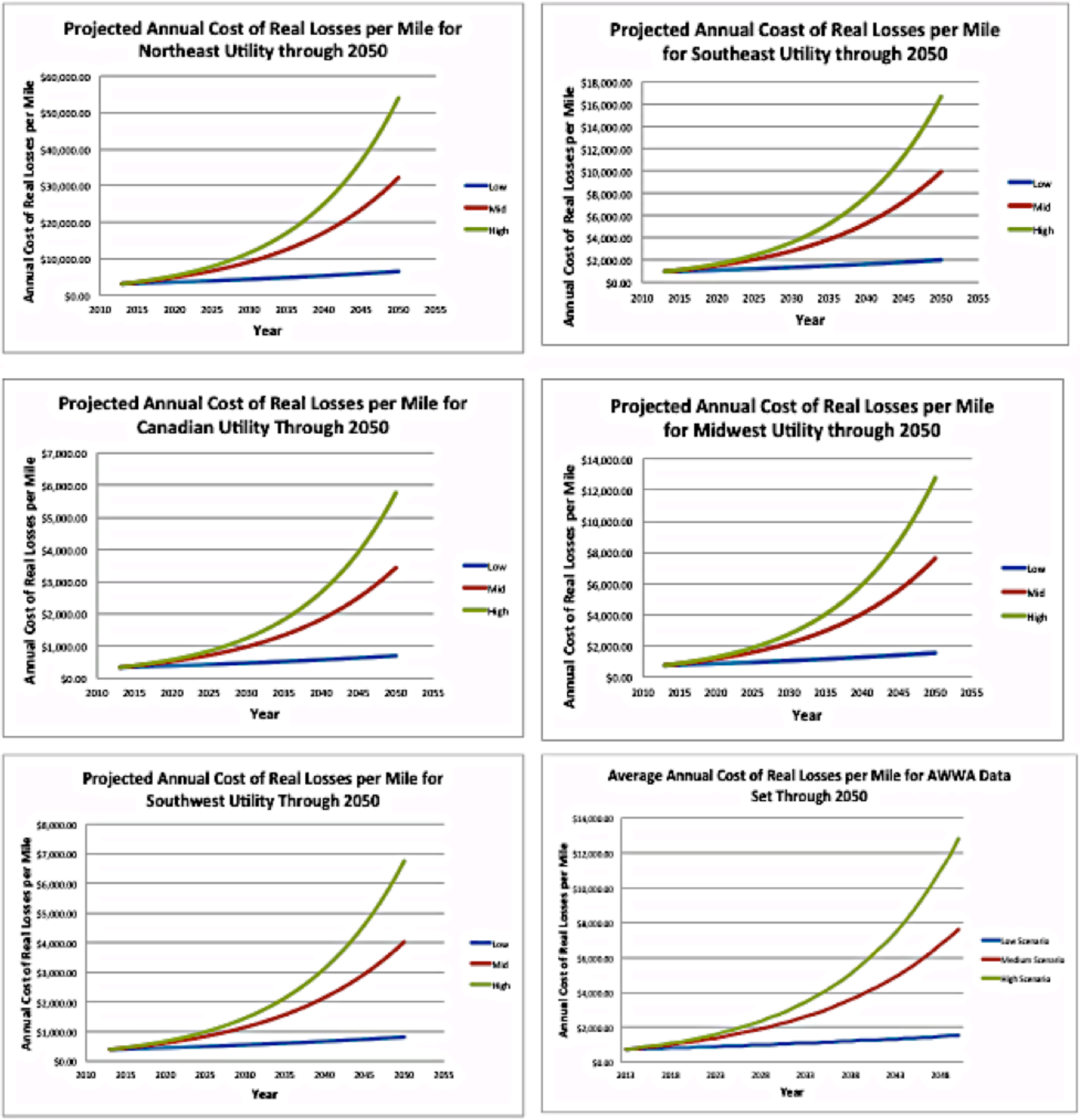

Figure 7: Low, Medium, and High Scenarios (2%, 6.5%, and 8% respectively) are shown for the projected annual cost of real losses per mile through 2050 for the various regions. Although they follow the same pattern, the actual cost (y-axis) varies significantly.

In order to visually compare the results from Figure 7, the graphs were combined into one as can be seen below in Figure 8. It is important to note that Figure 8 plots the medium scenario described in the previous graphs and is therefore assuming a consistent annual cost increase of 6.5% per year through 2050. The horizontal red line on the graph represents $2000/mile, which was the price point we identified as viable for PFT Technology's tracer. A more complete form of the graph can be found in the appendix.

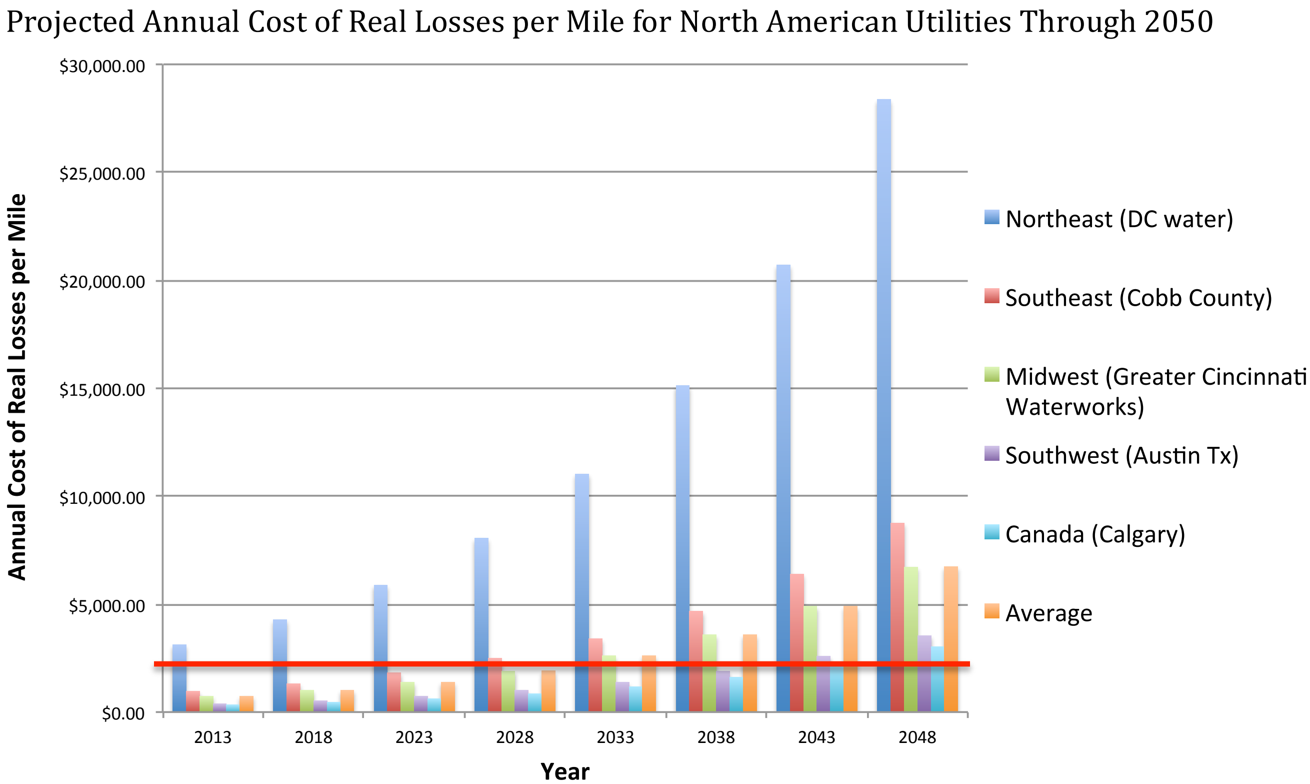

Figure 8: Comparison of annual cost of real losses per mile for the various regions through 2050. The red horizontal line represents $2000/mile, and is an example of how PFT can use this model to plan entry into the market based on a certain price point.

As one can see from the graph above, the Northeast is by far the most viable market. Based on the price point of $2000/mile, this is the only market that meets PFT's necessary margins. However, by 2050 all of the regions modeled in this report are expected to exceed this value. This suggests that PFT should enter the market by region as the different markets become viable over time. Based on our projections they should start with the Northeast and then target the Southeast, Midwest, Southwest, and Canada in that order. This result was intriguing since we had initially expected the Southwest to exhibit the greatest potential for this technology due to the water shortage and higher prices. However, after looking further into the issue, the age and size of infrastructure proved to be the biggest drivers of leakage, causing the Northeast to be the most appealing. This result is encouraging for PFT Tech since a large amount of the infrastructure in the Northeast tends to be in urban settings, which aligns with the technological advantages of PFT's tracer. This could potentially increase a utility's willingness to pay for the product as well.

Conclusion

Our analysis suggests there is large potential for our clients to implement their products in certain segments of the water industry. Initial market research showed the sectors with the most potential to be brownfields, underground storage tanks, nuclear, and utility supply, where water utility supply lines were the strongest option.

All experts interviewed believe that there is potential for tracing technologies on the market. They expressed cautious optimism that novel technologies would be able to replace the existing tracing technologies that were "good enough," when the cost of water rose or in areas or facilities where leak rates exceed the national average or a tolerable threshold. The experts believe that the cost of water will rise to meet the true cost over the next 20 years. These very knowledgeable scientists and policy makers did express concern with a perflouro chemical tracer in drinking water, and intimated this might be a hurdle in product implementation.

Legally, there are no restrictions that prohibit either of our clients' chemicals to be used in drinking water. However, there are potential policy restrictions that must be addressed. Chemicals used in drinking water must be tested at local, state, and sometimes federal levels before permits are approved. Flouride regulation poses an additional concern for PFT Tech. Current maximum loads are set at 4 mg/L, but the EPA has publically discussed a desire to reduce this number by half.

Our economic analysis predicts that the viability of these markets will grow over the next 40 years. We found that the drinking water utility supply market varies regionally and should be targeted accordingly. The projected annual cost of real losses per mile is highest in the Northeast US. This region is the only one that immediately crosses our threshold of $2,000/mile, however all regions will reach this goal by 2048.

Recommendations

1) Enroll product into health and safety testing immediately
2) PFT Technology should enter the Water Supply and Distribution markets regionally as price points are met
3) Base Trace should further evaluate the economics of Brownfields and Underground Storage tanks as potential profit opportunities
4) Both companies should further evaluate the Nuclear industry as a market option, with care to understand competing technologies.

Implementation

Health and safety testing is of paramount importance if our clients wish to implement their product into drinking water or most other water supply systems. There are a number of university and private testing facilities that are available outside of government that can be useful contacts. The NC Division of Water Resources should be the main contact point for these testing procedures as they will determine if the products should be considered contaminants or not. This process must be completed and the government must establish safety before any further steps may proceed.

At the same time, both clients should further evaluate opportunities in the Nuclear industry. We believe that both clients' technologies are applicable in this space, but have concern over potentially high barriers to entry as competing technologies are generally chemical tracers and are prevalent in this sector.

Once the tracers are approved, our clients should move to the next stage of our recommendations. We believe that Base Trace is best suited for the brownfield and underground storage tank market due to the properties of their tracer. We recommend that PFT Tech enter the water utility supply and distribution market for the same reasons. PFT should being by targeting high revenue northeastern utilities, such as the Washington Suburban Sanitation Commission, DC Water and Sewer Authority, or the Philadelphia Water Department. This is also an appropriate time to engage and create relationships with regulatory bodies in target areas. A pilot project in the northeast should be a strong indicator of future success with product implementation and allow time for the rising cost of water to make other geographic regions viable.

The final step will be to engage in a multi-regional market penetration based on our provided value projections. We projected that the cost of leaks will become an economic burden on most companies in the country by 2050. We estimate that utilities will cross our threshold of $2000/mile (cost of real losses per mile of pipeline) depending on geographic region and should be targeted at this time.

Appendix

Regulatory Analysis

This section provides the detailed legal and regulatory analysis summarized in the body of the text. This section reviews the Safe Drinking Water Act, Toxic Substances Control Act, state participation, policy concerns, and more.

Safe Drinking Water Act

The EPA defines a contaminant as "any physical, chemical, biological, or radiological substance or matter in water.[41]" The agency then sets limits on the contaminant concentration that may be present in drinking water at a given time. Water is required to be tested for contaminants and controlled using the best-available control technology practices. The EPA's power to regulate United States water systems comes from the Safe Drinking Water Act.

The SDWA, Title XIV of the Public Health Service Act (42 U.S.C. 300f-300j-26), aims to protect public drinking water from potentially harmful contaminants. Although the EPA is the main regulator of this law, much of the responsibility is passed on to the states through the Public Water Supply Supervision (PWSS) Program[42]. The EPA is authorized to name and regulate contaminants, especially those that pose health risks to the general public. Section 1412 sets the basis for selecting contaminants and provides guidance for how the EPA should handle the contaminant at hand. The SDWA gives the EPA authority over the over 160,000 water systems in the United States. This law describes and outlines over 91 listed contaminants that are found and regulated in the United States water systems.

The EPA makes regulatory determinations based on the guidance from Section 1412 from the SDWA, which sets the guidelines for contaminant determination. It requires that the EPA analyze three criteria: potential negative health effects, frequency and concentration of contaminants in public systems, and if the regulation provides a "meaningful opportunity for reducing public health risks[43]." Section 1412 (b) also states that the EPA must publish contaminant candidate lists (CCLs), for non-regulated chemicals and contaminants that may become a listed contaminant in the future. These lists are provided to the public and opened for comment, and research. This list currently contains over 100 chemicals and microbiological contaminants[44].

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[41] EPA "Safe Drinking Water Act" http://water.epa.gov/lawsregs/rulesregs/sdwa/

[42] Carter, Thomas. "Safe drinking Water Act and its Interpretation." Nova Science Publishers Inc. 2006.

[43] EPA Regulating Public Water Systems and Contaminants Under the Safe Drinking Water Act. http://water.epa.gov/lawsregs/rulesregs/regulatingcontaminants/basicinformation.cfm

[44] Environmental Protection Agency, "Drinking Water Contaminant Candidate List 3 - Final," 74 Federal Register 51850, October 8, 2009.

Once a contaminant is selected, the EPA goes through a regulatory process outlined by the SDWA. It must set a Maximum Contaminant Level Goal (MCLG), which is a non-enforceable limit determined to be the maximum concentration a contaminant can be in drinking water without posing a health risk to humans. Three major groups must be considered: Microbial Contaminants, Chemical Contaminants – Carcinogens, and Non-Carcinogens (not including microbial contaminants)[45]. The limits for microbial contaminants and chemical contaminants tend to be strictly defined, while there is generally some leeway for non-carcinogenic contaminants.

The EPA is required to conduct a risk assessment study when announcing regulations for new listed contaminants. They must, "1) use the best available, peer-reviewed science and supporting studies and data; and 2) make publicly available a risk assessment document that discusses estimated risks, uncertainties, and studies used in the assessment.[46]" The law also requires the agency to provide a health risk reduction and cost analysis (HRRCA) to help determine whether the benefits of this contaminant outweigh the potential costs.

State Participation

Section 1413 of the Safe Drinking Water Act gives individual states and territories the primary regulatory authority over their own drinking water systems. Similar to many federal statues, such as the Resource Conservation and Recovery Act (Title 42 U.S.C.), states must maintain standards as strict or stricter than the required federal standards. 48 of 50 states currently participate in the PWSS program.

Section 1452 authorizes the EPA to provide funding to states through the drinking water state revolving loan fund (DWSRF). These loans are made available to state systems that require assistance meeting regulatory goals, or for research and development. In fact, approximately $14 million a year is available for states to research the health effects of new drinking water contaminants.

In a similar vein, Section 1442 provides more than $30 million annually for research on health effects and other studies pertaining to contaminants. These funding sources are listed as potential opportunities to secure funding for the testing of a product, and could be used to assure regulators that PFT functions as a safe and secure tracing fluid. In addition, 1996 amendments to the SDWA, Section 401, allow the EPA to provide up to $50 million for research in infrastructure protection and maintenance.

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45 EPA "Drinking Water Contaminants." http://water.epa.gov/drink/contaminants/index.cfm#Organic

46 Congressional Research Service "SDWA Summary and Major Requirements." 2009.

Policy and Regulatory Bodies

The EPA has main authority over all drinking water systems, and states subsequently have primary authority as outlined by the SDWA. As stated above, our client's product is not a regulated substance, therefore it is not a contaminant, but still must be approved before being placed in a municipal or state water system. Our team interviewed multiple utilities and asked about the process of incorporating a new chemical into the water supply.

Reginald Hicks, the Superintendent of Regulatory Compliance at the Durham Water Authority, is in charge of keeping water supply in accordance with state and federal standards. He informed the team that addition of a new chemical is fairly commonplace, and occurs frequently throughout the year. Any chemical not naturally occurring in water must be permitted by the state. If Mr. Hicks wished to change the concentration, dilution level, or even isotopic composition of a given chemical, he would have to submit an additional permit request to the Department of Water Resources.

The North Carolina Department of Water Resources (DWR) is the regulatory body for the state. They will evaluate any requirements for new chemical additions. Generally, they will research and pilot test any chemical prior to it being approved for public drinking water. Most times this testing is done through computational modeling, however, on occasion the state will contract a consultant who will test it on a micro scale before passing a final ruling. Most states that operate under the PWSS program follow a similar path. Many times, the EPA will conduct their own testing and approve or condemn the use of a certain chemical compound. If this occurs, the state must follow the new federal regulations. There are no current rulings on the use of perflourocarbon tracers.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) allows the EPA to collect data on chemicals and to "evaluate, assess, mitigate, and control risks that may be posed by their manufacture, processing, and use.[47]" Section 5 of TSCA contains a list of chemicals and categorizes them based on different effects, especially environmental and human health. Section 6 of the same statute gives the EPA authority to suspend manufacturing or trading of a given chemical, and place restrictions on the use of the chemical if it proves to have a high-risk probability.

There are a few other federal laws that regulate water use in the United States, but they do not greatly coincide with the desire to implement PFT's technology into water. The SDWA contains a section known as the Underground Injection Control program (UIC) (40 CFR 144). This covers the injection of tracers into underground water sources. We do not intend that PFT will inject their product underground as a fluid tracer in this sense, but the UIC sets guidelines for the process. These tracers

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[47] EPA, Dept. of Agriculture. "Toxic Substances Control Act." http://www.epa.gov/oecaagct/lsca.html

must be reported before every injection, and cannot endanger sources of drinking water[48]. These regulations create an atmosphere mainly suited for multiple, short-lived injections of tracers, mainly used to track fluid movements underground.

Policy Concerns

Although PFT does not seem to face much legal opposition, subjective analysis and expert interviews suggest that the same may not be true on the policy side. To be clear, there appears to be no *legal* restrictions on PFT's technology as it stands today to enter the drinking water industry. However, regulators and the general public may react strongly to a compound with the prefix "per" being placed in their water.

The SDWA requires that utilities notify their customers about what chemicals and contaminants are found in the public water supply[49]. According to our experts, regulators might balk at putting a perflourocarbon tracer into the water, unless it is pronounced safe to use by the EPA. This is a notoriously risk averse industry when it comes to product implementation[50] and many managers might want to avoid the hassle, unless there are significant cost savings to be realized.

Recently, perchlorates, which have been used in drinking water, have been linked to cancer and other human health issues. Our research has uncovered preliminary data suggesting that perflouro chemical compounds may be unsafe as well. The successful introduction of PFT's product into drinking water, or anywhere in the water industry, will rely on both the concentration and health effects of the tracer being put into the water.

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[48] Holmbeck-Pelham, S., Rasmussen, T., and L. Fowler. "Regulation of Injected Ground Water Tracers." *Ground Water.* 38, no 4: 541-549.

[49] Tiemann, Mary. "Safe Drinking Water Act (SDWA): Selected Regulatory and Legislative Issues. 27 July 2010.

[50] Personal Interview, Michael Deane. Phone. Jan. 24, 2014.

SAMPLE INTERVIEW SHEET

Interview Sheet – Master's Project

Intro:

I am a graduate student at Duke University. My Master's Project is concerned with the issue of pipeline leaks in the American water industry. I work for two clients who provide novel leak detection technologies and are interested in entering certain water markets, if deemed feasible. Your expertise in this area is highly related to my studies, and I appreciate you taking the time to answer a few of my questions.

1. I was initially interested in this project when I learned that America loses 15% of its potable water to pipeline leaks. Does your organization have any data that I may use to quantify this in terms of lost monetary value?

2. There are a number of existing leak detection technologies already used today (mainly acoustic sensors and metering). Can you speak to how well these systems work? [If the client is from a utility] Does your company use any of these systems? What is your satisfaction with them?

3. Much of the nation's infrastructure is aging and in some cases, failing to operate at acceptable levels. Do you believe that the best course of action is finding leaks in pipes and fixing them, or replacing large amounts of pipelines all at once?

4. Based on your experience, would you say that utilities care about the lost water? Why or why not? If not, do you think they will feel differently 20 years from now?

5. Is water scarcity something that you talk about in your day-to-day life? Is the threat of being water limited driving strategy talks or other initiatives in your work?

6. What are the main regulatory hurdles you anticipate for me implementing a product like the one described into the water system? Are there areas of the industry that you would imagine it being more successful?

7. How do regulations such as the Safe Drinking Water Act play into your every day work life? Are there laws that play an important role?

8. If water scarcity is an issue of increasing gravity, how do you think this will impact the country in 10 years? 20 years?

9. Do you see private utilities taking a larger share of the overall utilities market? Why or why not?

10. The cost of water in America is very low today, making investments in the water industry difficult to strategize for, and in many cases, not profitable. Many investment banks have anticipated a rise in the price of water, and a large increase in investments and returns. Do you agree with this outlook? What do you see the cost of water doing in the future?

11. If you believe the cost of water needs to be higher, how do you think change should be implemented? What are the most effective ways to educate the public on the issue?

12. In your opinion, what is the biggest barrier for new technology being implemented by utilities?

13. Are there any government programs you know of that encourage technological entrepreneurship in the industry?

14. What do you think the face of the water industry will look like 20 years from now? Will water scarcity be a major player in driving industry changes?

Expert Engagement

Experts Interviewed:

Martin Doyle – Duke University
Dan Vermeer – Duke University
Fred Pfiefer – Washington Suburban Sanitary Commission
Tom Roberts – Aqua – Lecture, not interview
Jim Salzman – Duke Law
Tracy Mehan – Cadmus Group
Michael Deane – NAWC
Reginald Hicks – Durham Water Authority
Alan Robeson – AWWA
Jim Taft – ASDWA

The following includes summaries of the conversations based on the interviewer's notes. Any material that may be deemed "sensitive" has been removed from the summary, but included in the expert subjective analysis section, without credit to the interviewee.

Ten experts with intimate knowledge of the water industry were interviewed on the topics of leak detection, water prices, infrastructure, and more. A full interview sheet may be found in the Appendix. The interviewees came from academia and business, with experience in law, chemical treatment, policy, utilities management, and supply chain management. The interview process provided the consulting team with subjective probability and knowledge with which to base their recommendations on.

Martin Doyle – Duke University Professor

Martin was an early interview, as the project was just beginning. He expressed excitement and optimism about introducing a tracer to drinking water, or other areas in the industry. He figures that with 9 million miles of water piping and a 14% national leakage rate, there could potentially be value proposition in this market.

When asked where he thought our clients would best fit in, he mentioned a number of sectors to research. He suggested we look into both the private utility side of the water industry and conduct a case study on an old city to see how many miles of pipeline had to be replaced in the last 50 years. This suggests a potential value opportunity for our clients. Wastewater leakage was also an important area, because although wastewater is gravity fed, it must be pumped uphill, where incidents may occur. Distribution lines offer miles of pipeline which could potentially be valuable.

Dr. Doyle sees two main scenarios to come from this project: 1) We can't get approval to put the product into the water supply, so we will have to determine an alternate direction for the company. 2) If we can get it into the water supply, we need to provide the "scale of opportunity" to implement the product. He also provided us with names of experts in different areas to talk to.

Update: Further talks with Martin brought up the potential opportunity to get the product tested by a potential customer, which must remain non-disclosed until a later date. We are beginning talks to have our clients' products tested by very large potential customers in the near future.

Dan Vermeer – Duke University Fuqua School of Business

Dan Vermeer is a supply chain management expert and has championed sustainable water usage in large companies. Dan outlined the economics of this issue and noted that water is so cheap, especially in the United States that people aren't encouraged to invest in this space. He provided us with some large-scale market reports, including a Deutschebank survey on global water markets, which suggested, somewhat contrarily, that water is a very good investment, because water is becoming an increasingly scarce resource.

Following the business theme, Dan provided us with a number of companies involved in leak detection that would provide competing projects or set precedents on how best to advice our clients to proceed. He also provided us with a number of resources including the EPA gap report, a survey by the company Xylem, and names of experts in the field to contact.

Fred Pfeifer – Washington Suburban Sanitary Commission

Mr. Pfeifer is the Asset Strategy Manager at WSSC, a public water utility in the Washington DC metropolitan area. He spoke candidly about leaks and gave lots of inside information on feasibility for this project. WSSC has 5500 miles of pipe, 4600 of which is distribution piping, which is piping under 16 inches. The rest is transmission piping, running from 16 to 108 inches in diameter. He pays $2.75 per 1000 gallons of water, and $3 per 1000 gallons of wastewater (for disposal).

WSSC experiences a 14% loss of non-revenue water (mostly leaks), and he wants to get that number to 10%. They use mainly acoustic sensors for their leak detection technology. He recently completed a pilot on the acoustic detection technology and determined it worked well enough for them to continue usage. However, he says that it is not uncommon to develop new technologies.

When asked about his opinions on adopting a new tracing technology, he said that unfortunately, the fact of the matter is that water is so abundant on the east coast that it is not really an important priority to minimize line leakage. There is little value because water is so plentiful, and also as a public utility, he has the costs of leaks baked in to his customer's rate structure. To him, the ancillary effects of leakage – soil subsidence leads to caverns under the street, which can lead to sink holes – are more important. He says that this is a fairly low tech and highly competitive market however, with automated metering infrastructure a main way to detect these problems.

Fred noted that "weeping leaks" – small leaks that cannot be detected by sensing technology - cause the biggest problem. These can waste large amounts of water and can be almost impossible to find and fix. Any technology that could minimize the amount of digging to fix a leak like this, he said, would potentially create large amounts of value. Currently, it costs about $7500 to repair one leak. This works on a technical level but is very hard to sell to management.

He said that pipes are actually in pretty good shape even though most in the DC area are over their life expectancy by 15 years. He did an acoustic test not long ago on a sample set of pipes and found 80% of them to be in good condition. He warned that corroded pipes come from near where there were repairs, and that the high profile line breaks in the news are a bad indicator of the aggregate.

Finally, he suggested that our clients should look for two characteristics in their potential customers – private ownership and good location. Private systems also have leaks "baked in" to their rates, but should be willing to adopt technology if it will save them on the bottom line. Cities are also more risk averse than private companies, so there may be a better chance of production adoption there. He also suggested looking to the arid southwest, to areas such as Arizona, Texas, California, or New Mexico. Water loss is not a compelling argument for value proposition except in certain areas of the globe.

Representative – Aqua NC (Team attended lecture, did not interview privately)

We spoke with an employee of Aqua NC, a private water utility that operates in the state of North Carolina. He attended Duke University to give a lecture on private utility operations. He stated that Aqua NC invests between $10 and $15 million each year on infrastructure. They operate under a $4.6 billion market cap.

Aqua NC's infrastructure issues mainly stem from pipes that have organic and sediment deposits building up on the inside of pipes, leading to a decrease in diameter of the effective pipeline and a constriction of the water flowing inside. He says that $16 billion needs to be invested in NC for all water uses over the next 20 years.

The employee says that the overall trend is that people are becoming more efficient in their water use. This means that companies have to raise the water sales price in order to recover their capital expenditures. In fact, 21% of North Carolinians reduced their water usage by over 20%.

He spent some time talking about what needs to change. He wants full cost pricing (operating expenditures, transportation, etc.) across the board. One must also factor in depreciation. He stated that there are two types of infrastructure investment – proactive and reactive. In a private question with the representative after the lecture, I asked him about water leakage rates, and if private utilities would be more willing to adopt technologies to detect leaks, even though structures were baked in. He said that he would be interested, as any businessman would, to listen to a sales pitch. Efforts to increase his bottom line are always welcome, but it would have to come at an affordable cost.

Jim Salzman – Duke University Law School

A short, in-person interview was conducted with Jim to analyze the legal aspects of placing tracers in water, and specifically drinking water. Jim is the author of the book, "Drinking Water", which provides a pseudo-legal look at the history of drinking water and the many effects drinking water production has on infrastructure, the economy, policy, and more. His book provided a good amount of relevant information for this project, so I decided to follow up.

Jim stressed the importance of the Safe Drinking Water Act, and provided sources for summary documents provided by the Congressional Research service. He outlined that the SDWA deals with what's allowed to be in the water itself. It sets national standards for drinking water. He told me that I need to find out what I'm allowed to add if its not an MCL. Jim directed me to contact the compliance authority at Durham Water Authority, to ask his or her advice on what they do and what laws they deal with when they want to add something to the water. There should also be a number of state laws that apply to the same concept, and the people at DWA should know that as well.

Tracy Mehan - Cadmus Group LLC

Tracy Mehan, the Principal at Cadmus Group, was interviewed by phone. Tracy is a policy expert and very well connected in the water industry. He voiced optimism at the project and noted that leak reduction is a very important issue, especially moving forward into times of increased water scarcity. Mr. Mehan spent the majority of the time connecting me with people throughout the water industry. He also named some systems, such as DC water, that use a very sophisticated metering system to track leaks. This company sets a baseline, and sends pipeline information to customers. Apparently they are even able to "talk" to leaks. This advanced metering has the opportunity to reduce capital investments.

Tracy gave me a number of names of people across the industry to talk to. He said that he himself is not well versed in the issue of pipeline leakage, being a policy expert, but knows that regulations are increasing to fund infrastructure repairs and efficiency measures.

Michael Deane – National Association of Water Companies

Mr. Deane is the Executive Director for NAWC, which represents private water utilities across the country. He starts with saying that the industry has neglected water loss, but now there is an increasing driver for it. I asked his thoughts on putting a tracer into drinking water and he said there would be lots of uncertainty. Mr. Deane told me that existing systems, such as acoustic and metering work, and they work fairly well. There would have to be a strong value proposition for a company to switch onto something new, but if the product was approved to be put into water, it would be something to consider.

I asked Mr. Deane about the balance of private and public utilities 10-20 years from now, and he answered that it would be probably about the same (Note: Current US utilities are 85% public, 15% private, approximately). He stated that we could see a rise of public/private partnerships, where cities and private utilities divvy up responsibilities, but the overall market share will remain about the same.

Water scarcity will continue to be a big issue in 20 years. It will drive us towards collaboration and technological innovations to improve water use efficiency. He thinks the main response to water scarcity will come from some form of technical innovation. He also added that public utilities don't care as much or manage risk as well as private utilities, who would be more likely to take on novel technologies to reduce water loss.

NAWC focuses much of their efforts on teaching. Some of the biggest challenges are teaching people that water costs money and needs investments. They know we have infrastructure, but don't understand that they're deteriorating and we need to act. They try to teach people that we have stringent public health standards, it's more costly now to put pipe in, and the very inexpensive water service has to end. We need to get people to understand that you have to invest in infrastructure. People don't want the cost of technology to go into their bills, and they really don't understand their personal connection to what it takes to deliver that water. It is a "horrible" job to get people to understand how expensive water actually is from infrastructure repairs, operations costs, and technology costs.

In response, I asked him if the government will ever be able to get to the point where they charge the real price of water. Mr. Deane answered that they will, at some point. Municipal utilities have been very bad at it, but private utilities have been much better. However, it is becoming more difficult to raise rates. When rates are cheap it is fairly easy to raise them, however people are starting to notice their water bills and complain about the rates a lot more. Private utilities can be much more efficient, especially over the lifecycle of the facility. As water becomes more efficient, it will drive more efficiency. Ten years ago, that was the driver. Today and in the future, the value proposition will probably be in public-private partnerships. Water is worth the demand, and as water scarcity increases so will the price, although it will be volatile.

Reginald Hicks – Durham Water Authority

Mr. Hicks is the Superintendent of Regulatory Compliance at Durham Dept. of Water Management. He is responsible for the chemicals that are put into the drinking water. When he adds chemicals, he has to get a permit with the state. If there are any changes (such as new chemicals) he has to send it to DWR, and have them evaluate it and pilot test the chemical before it can be put into the water. He says that the addition of chemicals into the water is fairly common. For instance, they frequently change their corrosion inhibitor to keep up with new standards.

There are other things to think about when adding chemicals. Is there a dilution issue when you put it in? Think about precipitation, coagulation, and the distribution systems. To the corrosion inhibitor example, the EPA came out with a guidance that decreased the amount of fluoride allowed in the water. Once it was approved with the EPA, it was approved by the state, and then he could continue on.

Durham uses AWAR meters for their leak detection. These collect data and determine how big the leak is. They also use these meters to run water audits to gauge pipe health and water efficiency. The system for adding chemicals to the water is fairly simple: One determines the amount of chemical you want to put in (generally increase but sometimes new chemical), and you model it to see the effect. Generally they bid this out to a consultant who runs computer models or builds a model on a very small scale to analyze feasibility.

Alan Robeson – American Water Works Association

Mr. Robeson is Director of Federal Relations at AWWA. He is an expert on almost all stages of the water industry so we were able to stay mainly on script and follow our example interview sheet.

I asked do companies even care about leaks? He answered – “Yes and no.” He said that some companies lose 30-40% of their water to leaks, and they definitely will care. You’ll see more that people will care about not just the cost of water (lost revenue), but GHG and C emissions. We (AWWA) are invested in embedded energy in lost water. In water scare areas there might be a lot of pressure to drive that number down, and have requirements to get leaks down to a lower number.

When asked about if there are concerns about putting our chemicals into the water, he said there are some initial concerns, but of course he does not know the exact chemical compound, and it must be tested and approved for anyone to pass judgment. However, he says there are problems with perflouronated compounds already. A lot of companies might balk at putting a chemical with that name in their water. However, chlorine is toxic, but companies understand their doses and put some in the water. It may become more acceptable with more knowledge and testing, but not everyone would be interested in placing this in their water. It could hurt from a PR standpoint as well.

Questions on infrastructure, his 20 year projection: We will replace all the pipes within 50-100 years. Not 20. There's time to do it. It makes the payback a lot further down the road, and it's definitely a big investment. Helping people understand the tradeoff between replacing the pipe and finding and fixing a few leaks could help the cost benefit pay off. You could approach it as instead of just leak detection savings, say, "if you invest $x, you can extend the pipe life by 10 years, save 10% of your price and show the cost savings there." You'll need to quantify the cost savings to sell this product to companies.

There are no legal barriers. There would be a lot of people interested in leak detection, and more and more people are becoming interested every year. He then provided me with data from AWWA on non-revenue water loss that has been tracked by 30 companies around the country.

Alan also shared the opinion that private utilities will probably maintain the same relative market share in the future that they do now. He says you may have areas where you have more contract operations, but he says a lot of public utilities are actually more efficient, because there is less pressure to operate the treatment plants, handle the billing, but own the assets. He cites an 80-20 public-private spread and notes that most of the big cities are public entities.

The cost of water is lower than the real costs in some places, but in some places, people pay the real cost. DC is full cost. Infrastructure costs will drive the rate of water up. Most of the costs lately are for meeting new regulations, and taking baseline testing. They only replace 1% of their pipes.

There are no real government programs for entrepreneurship. Technology should be looking for niches and to start making money. Tech in the water sector is pretty slow because most of the large technology can only be purchased by the biggest 400 companies. It's harder than people think. In terms of leak detection, most people are happy with the existing technology because its, "Good enough." In the future if water prices become very high and cause that 15% to mean something, then technological innovation might be needed on this front. The sector as a whole is very risk averse, and people are happy staying with existing technology.

Jim Taft – Association of State Drinking Water Administrators

Jim Taft is the executive director of ASDWA. Although most people interviewed were generally positive about the feasibility of our clients' products being applied to drinking water, Jim seemed the most enthusiastic. He told me the following:

There is a huge leak problem. Extreme weather, climate change, and more are driving water issues. Over the last 5 years there has been a greater focus on water conservation and leak detection, but all at a high level approach. Utilities are trying to get rid of water loss. The ARRA allocated $2 billion for drinking water and $4 billion for wastewater improvements, with special considerations for "green tech."

Water efficiency is huge and will continue to be a big deal in the future, and the first step in solving that is leak detection. There are lots of opportunities, because the infrastructure is very old. You need to have not only an effective technology, but the *right* technology. This is not going to be easy, because the sector is risk averse and many people are set in their processes.

The key is getting to the thought leaders. You need to find the water utilities to give it a shot, and show that it's *cheaper* and *better.* Energy costs becomes part of this equation, so you need to show that water conservation is a win/win. Block costs are very bad.

Utilities are getting a better handle on their finances. However, there are tons of small systems and their data collection and finance is rudimentary at best. The EPA has implemented the CUPS program, which provides financial planning and asset management assistance. If you can identify the problem for them it will open up the door for new markets.

In terms of regulatory environment, the biggest question is what is the concentration of this chemical in the water? Perflourocarbons are an area of concern as a contaminant. You need to show that there are only truly minute effects, and that this will work well at a highly diluted level. The regulatory *hurdles* will be challenging the perception and proving that this is a safe chemical throughout the industry.

Public private utilities in 20 years will be moving towards the structure of oil. Water is an undervalued commodity and it won't be in the future. Look out West now, it is already highly valued, and they haven't seen the worst of it to come. It's even spreading to the East Coast, where some places are seeing drought conditions in the summer and no one knows how to handle it. This is going to make technology very important and much more valued in the future.