The Future of Water Reuse in America

Subcommittee Hearing
Subcommittee on Energy and Environment
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Prepared Testimony
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Overview

Water reuse is not new to America and there are a number of well known large scale reuse projects that are mostly in the arid regions and they almost exclusively use treated wastewater effluent for irrigation purposes. Arguably, if this causes the irrigation of additional arid land, it does not offer any real environmental benefit but if it replaces existing irrigation supply, it does reduce the demand on water supply. Such water reuse projects are accepted by the public and they are beneficial, but the benefits are mostly seasonal and only of significant value where irrigation is in high demand.

Direct water reuse is a more beneficial and innovative approach whereby wastewater is treated and reused for multiple nonpotable purposes inside and outside of buildings. This has been accomplished mostly on a distributed system basis where small to medium size facilities are built on-site to provide service to a specific customer or customer group. Typical uses are for toilet flushing, cooling tower make up and laundry uses in addition to landscape irrigation. There are 30 such direct water reuse projects in the Northeast and they span a period of 20 years. Most recently, such projects have been built in urban areas where an abundant supply of wastewater can be readily minded for treatment and reuse. The benefits of this approach are numerous:

- 48% to 95% reduction in water consumption by comparison to typical modern buildings
- 60% to 95% reduction in wastewater discharge
- Reduced environmental impact from Combined Sewer Overflows (CSO)
- Reduced nutrient and chemical loads to water bodies
- Consistent performance year round that is not dependant on geographical location or season
- Economical operations that use the waste as a resource, provide treatment at the source and yield a favorable Life Cycle Cost and Life Cycle Assessment

- Economical asset management that avoids the need for large capital projects associated with conventional centralized water and wastewater systems
- The opportunity for improved energy efficiency relative to water and wastewater treatment systems and water movement in general
- The opportunity for improved nutrient management for further environmental benefits

By way of example, for a mixed use (residential – commercial – office) development it is very possible that the nonpotable water reuse demands would nearly match the wastewater generation such that wastewater discharge can be almost entirely eliminated. Such dramatic results are not widely recognized and embraced within the water and wastewater industries for many reasons, mostly due to lack of understanding and difficulty adopting innovative models. There is a strong need for education via demonstration projects as well as research to advance knowledge within this field so that the centralized water and wastewater industry can enter this new paradigm.

Introduction

It has been reported that it takes 1,200 gallons of water per capita per day to operate the U.S. economy but the human population only consumes less then 1 gallon of water per capita per day. It is clear from this fact that water reuse offers tremendous opportunity to reduce our impacts on water resources because theoretically all but the 1 gallon per capita per day can be readily reused. Water reuse is not new, but it is not well recognized for the potential benefits that it offers because the entire delivery mechanism for water and wastewater services in America; regulatory, financial, legal, business and physical assets, are not structured to embrace the water reuse approach. Recent experience with water reuse projects in urban, suburban and rural settings suggests that these hurdles can be readily overcome with new technology and business delivery mechanisms that deserve widespread consideration because they have proven significant environmental benefit.

Throughout the world, we are faced with a situation wherein our water resources are being depleted and destroyed as a result of:

1. Growing population and pursuit of better living conditions that include abundant use of water for many lifestyle demands
2. Increasing discharge of new products that include more complex chemical constituents that are not readily removed by traditional wastewater treatment
3. Growing anthropogenic pressures on water resources from many activities that have indirect impacts

To date, we have approached the solution of all our water resource problems by innovating and advancing the supply and discharge mechanisms originally created by the Romans. This Romanesque approach relies upon the natural water cycle to provide the dilution and ultimate purification that protects human health. Unfortunately, what worked for the Romans is no longer suitable for modern humanity and we must take the necessary steps to establish a new perspective. The good news is that there are robust and well proven solutions available today.

If one takes a high level view our current conventional methods of water resource management, the problem becomes readily evident. Consider the following abbreviated technical description which represents our current approach to water supply and water resource management:

1. Supply - Surface and ground water provide our source of supply. These supply sources are compromised by many influences and are generally in need of treatment to remove contaminants and to provide disinfection from pathogens. Not all contaminants and pathogens are easy to identify so we constantly search for a better understanding of how to best protect our public health from many unknowns.
2. Storage - Most population centers demand more resource then can be readily supplied by the naturally available resource during dry weather periods, so we construct large reservoirs and dams to hold water to make up for natural deficits that would occur. This water impoundment approach itself has a number of detrimental affects on the environment and the water budget overall, but it is necessary and unavoidable in most cases.
3. Treatment - The extracted supply is treated, disinfected and readied for distribution. We strive to have this water as pristine as possible and recent testing has proven that it really is *as "pure as bottled water*" in almost all respects and cases.
4. Distribution - The treated supply is distributed via thousands of miles of pipes via pumping, pressure controls and intermediate storage tanks. This infrastructure is extensive, complex and is generally deteriorating and in need of repair. Pipe leakage generally accounts for a loss of about 15% of this rather costly resource.
5. Use - This "*bottled water quality*" supply is then brought to our homes and business where a tiny percentage is consumed, but most is used for flushing toilets, bathing, washing dirty laundry and dishes, cooling system supply in larger buildings and watering lawns and landscaping.
6. Contamination - As a result of our use, this supply is highly contaminated with feces, urine, chemical cleaners and disinfectants, dirt, unused products, industrial byproducts, food waste, grease, oil and a long list of things that go down the drain such as pharmaceuticals, personal care products, make-up, insect repellant and more.

7. Collection - In all urban and most suburban cases, this contaminated wastewater is then collected by another set of complex and cumbersome pipes and pumps that are also in need of maintenance and upgrading. Most of these pipes allow groundwater and stormwater to leak into the sewage (infiltration) and some allow untreated sewage to leak out into the ground (exfiltration). In most older urban areas and in far too many newer suburban areas these piping networks are influenced by stormwater flows and groundwater such that raw sewage routinely overflows during wet weather thereby contaminating the very source that supplies our drinking water.
8. Treatment - The collection and transmission system then takes this highly contaminated water to a central treatment plant where technology has been applied to treat and remove the contaminants to the greatest degree possible. This task becomes very difficult because some contaminants are difficult and expensive to remove and these plants are in need of upgrades and can not often comply with their requirements and customers don't want to pay for the required treatment plant improvements. There is also additional complication from the fact that new contaminants appear routinely as a result of new products that enter our market place and end up down our drains.
9. Discharge - These complex treatment systems do the best they can with the money and technology available and once fully processed, the treated water is discharged back into the water bodies that serve as the source of supply. Often, downstream neighbors remove this same water and begin this cycle all over again, in many cases with only hours of travel time.

If I were to suggest to you that you should flush your toilet with bottled water you would appropriately respond that this would be a crazy thing to do. However, this is essentially what we do under our current water and wastewater infrastructure paradigm. The above scenario could readily be condensed into the following brief non-technical description:

> *We utilized large scale public infrastructure to produce "bottled water" that we then use to flush our toilets and into which we dispose of our wastes, which we then send off for treatment and discharge into our water bodies, where henceforth we send it downstream for our neighbors to extract once again, produce "bottled water" and start the cycle all over again.*

When population density was low and waste sources were mostly biodegradable natural contaminants, this scenario worked because Mother Nature provided the dilution, disinfection and purification needed to buffer the dangers. Now that population densities are much greater and the contaminants are much more difficult to treat, this scenario makes no sense and in the long term must be replaced or supplemented by a more modern approach.

Direct nonpotable water reuse[1] offers the alternative of creating a man-made water cycle that separates the waste flow from the drinking water supply source and it provides high quality “nonpotable” water for uses that only involve waste disposal and do not threaten human health via consumption. Technological advancements allow small scale applications of treatment that can be placed immediately at the customer’s location such that the wastewater can be collected, treated, stored and reused without traveling long distances and without the associated large capital investment in infrastructure. Due to the nature of this “man made water cycle” the level of treatment is very high and the environmental impact is greatly reduced. The end result of distributed direct water reuse is a dramatically reduced demand on potable water supply, wastewater treatment systems and the water environment, plus elimination of most of the intermediary infrastructure required in conventional systems. It is a win-win throughout the water supply chain.

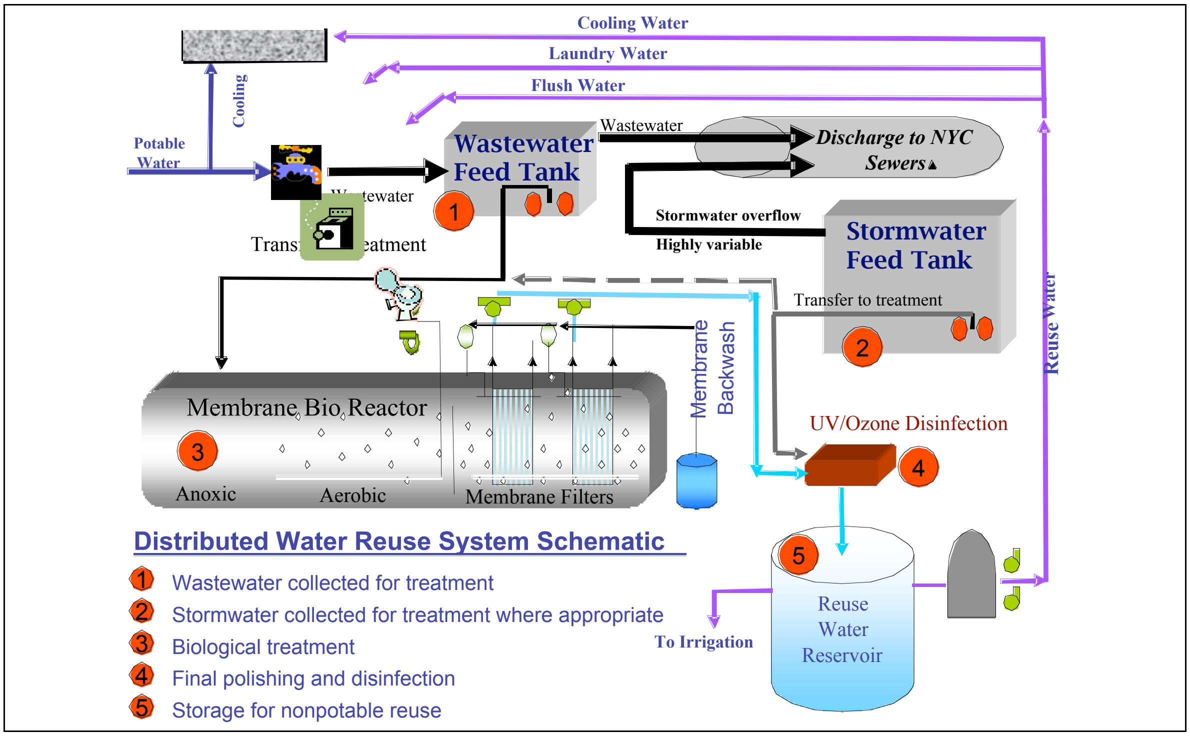
Brief History of Distributed Water Reuse Systems and Performance

This historical review is important as a means of demonstrating how distributed water reuse systems are already providing robust and safe service to a diversified range of customers over a significant period of time. The concept is not new, but as time has progressed, each new system has achieved improved results and more significant benefits. The concept is still very young with regards to development potential and there is a strong need for public education and research to build upon this successful start. Whereas it seems like we have come so far, in reality we have only begun to reveal the possibilities of water reuse that lie ahead.

The approach to distributed water reuse, sometimes referred to as wastewater mining is relatively simple, but it incorporates sophisticated advanced methods of treating wastewater such that it is completely safe and suitable for nonpotable reuse. The schematic presented below represents the current state-of-art relative to distributed water reuse systems. The membrane bioreactor has become the standard biological treatment method utilized presently because it offers several advantages – small footprint, robust performance and automation capabilities. As depicted in this schematic, stormwater can also be incorporated into the water reuse scheme depending on site characteristics and appropriateness of this additional source of supply.

[1] Nonpotable water reuse refers to water that is produced to a quality that is safe for human contact, i.e. swimming water quality, but not suitable for drinking. Direct nonpotable water reuse in this report never refers to direct reuse for consumption purposes. Direct reuse for consumption purposes would be objectionable to most Americans today even though technology now allows this as a safe practice as evidenced by new systems that are operating in Singapore.

Typical Distributed Water Reuse System Schematic



In the mid 1980's there were a rash of sewer-bans throughout the northeast that resulted from problems associated with aging wastewater treatment plants. This was also an era of economic boom that frequently created pressure to build new developments in areas where public sewers did not exist or where they could not accommodate any additional flow. This drove developers to seek alternative solutions and as a result of this economic driver, the first water reuse system in this region was built in 1987 for a pharmaceutical company in a suburb near Princeton, New Jersey. This 350,000 SF office research facility employed over 400 workers and by recycling treated nonpotable water to flush toilets, produced a wastewater discharge that was slightly more then a single family home. The results were so astounding that others soon followed suite.

By the late 1990's there were 20 similar systems built in the Philadelphia to Boston region and the applications represented a wide array of commercial, office, public buildings and one baseball stadium. Several schools were included in this portfolio which included children ranging in age from preschool to high school. Table 1 below provides a summary of these systems by age and type.

Table 1

Building Type	Date of 1st System	Water Reuse	Water Uses
Research	1987	95%	Toilet flushing
Office	1989	95%	Toilet flushing
School	1990	75%	Toilet flushing
Commercial Centers	1993	70%	Toilet flushing
Stadiums	1996	75%	Toilet flushing
Urban Residential High Rise	2000	50%	Toilet flushing, cooling, irrigation and laundry
30 Systems	**20 Years**	**80% Reuse Nonresidential** **50% Reuse Residential**	

In 2000, a water reuse system was built for Gillette Stadium, home of the New England Patriots, NFL Football Team located in Foxboro Massachusetts. This system raised the awareness of many interested parties because it not only provided a means for the Town of Foxboro to accommodate a new stadium, it also allowed for a nonpotable water reuse system that could provide the needed water and wastewater service to the Route 1 commercial district that is a vital component of the town's economic growth plans.

2000 was also the beginning of the Green Building movement in America and new development projects certified by the United States Green Building Council were now gaining attention. In New York City, the Battery Park City Authority had adopted strict environmental standards for the development of an area of southern Manhattan known as Battery Park City which runs along the Hudson River waterfront. Developers in this area embraced these environmental standards while also adhering to the USGBC LEED (Leadership in Energy and Environmental Design) program. Under these dual environmental programs water conservation and reuse became a key aspect of residential developments that aimed to achieve new levels of environmental excellence and demonstrate new innovations in sustainable urban development.

The first building, The Solaire, was a 293 unit residential high rise that broke the barrier and became the first building to incorporate direct water reuse in a residential setting. This project went on to be awarded LEED Gold certification by the USGBC and is widely recognized for its environmental achievements. After beginning operation in 2003, three years of water flow data clearly illustrated that the building consumed 48% less water and discharged 60% less wastewater then a comparable modern residential building in New York City. Water reuse at The Solaire incorporated toilet flushing, cooling tower supply and irrigation of the neighboring Tear Drop Park.

Subsequently, a number of new residential buildings in Manhattan have utilized this approach and there are currently four systems operating and there are expected to be a total of seven similar residential water reuse systems by 2009. The systems simply mine sewage and treat it to produce a high quality nonpotable supply source. As the bar continues to rise within this innovative green building market, new buildings continue to strive for even higher objectives. Projects now under construction include laundry supply as an additional use for reuse water and thus the performance results are expected to be even more impressive in the future.

An unanticipated benefit from this urban application of distributed water reuse is the fact that the reduced waste discharge to sewer lines helps to mitigate the affects of combined sewer overflows via lower flows and lower waste loads. Recognizing the public benefit gained from this approach the New York City Department of Environmental Protection implemented the Comprehensive Water Reuse Program in 2004 that offered building owners a 25% reduction in City water and sewer charges for water reuse systems that reduced demand by 25% or more. This incentive helped level the economic playing field between the privately funded water reuse systems and the publicly funded City water and sewer system. Currently, a capital incentive program for water conservation and reuse is under consideration to enhance this initiative further.

As per the objectives of PlaNYC 2030, the City expects to add 1 million residents, 750,000 jobs and accommodate more guests while reducing water and sewage flow by 5.5% or 60 million gallons per day. This ambitious goal will require a number of special measures to reduce and reuse water, with distributed water reuse being one component.

Benefits of Distributed Water Reuse

There are numerous benefits to the concept of distributed water reuse systems. They are highlighted in the bullets that follow:

- Water reuse in general reduces the demand on water supply resources and facilities on a gallon per gallon basis. Distributed water reuse systems also reduce the burden on centralized wastewater facilities similarly.
- Distributed water reuse systems utilize wastewater as a resource. Because the wastewater flow increases in parallel to the increase in water demand, there is no need for very large storage reservoirs to account for droughts. The supply and demand functions are closely linked whereby the resource flow increases while the supply demand increases and vice versa.

- Distributed water reuse systems offer the ability to separate wastes from the natural water cycle by creating a man-made water cycle that captures and treats wastewater and supplies nonpotable water for reuse.
- Distributed water reuse systems are located at or very near the customer, thus there is very little need for collection and distribution piping. In many cases, both rural and urban, the actual water reuse system is located within a customer's buildings and there is no need for any outside collection and distribution system. As a result, the huge problem of infiltration and exfiltration are completely eliminated.
- Because the wastewater is treated in one treatment process that produces nonpotable water, there is only one treatment mechanism to handle both the wastewater and the nonpotable water supply needs as opposed to separate wastewater treatment and water supply treatment facilities typically found in conventional centralized systems.
- In areas where the sewage is mined from a public sewer system, distributed water reuse reduces both the flow and waste load on the collection systems and the environment and thereby helps to mitigate combined sewer overflows and sanitary sewer overflows conditions.
- Because the reuse water must meet high quality characteristics to be suitable for reuse, it is treated in a manner that generally removes large quantities of nutrients that would mostly pass out into the environment in conventional facilities. This nutrient control aspect offers significant environmental benefit to the local water bodies that would normally have to absorb these nutrients.
- For added performance efficiency, distributed water reuse systems can also incorporate stormwater as an additional water source where climate and site conditions warrant.

Drawbacks of Distributed Water Reuse

The drawbacks of distributed direct water reuse systems are few, but they present important obstacles to more widespread application.

- Water reuse requires a dual plumbing supply system, one for the potable supply and one for the nonpotable supply, thus increasing the plumbing costs within buildings.
- Distributed water reuse systems are generally at a small to moderate scale and thus lose the economy of scale benefit realized by large capital projects. This drawback seems to be mitigated once the distributed water reuse system reaches a size of approximately 500,000 gallons per day of capacity which represents a neighborhood scale.
- Distributed water reuse systems are not subsidized with public funding as are centralized systems thus the costs to the customer are higher. Incentives such as that in New York City help to mitigate this difference.

- There is a general lack of understanding of distributed water reuse systems in the professional community and this approach is not routinely considered in water resource planning efforts except on special Green Building type projects or where public water and wastewater infrastructure does not exist. There is a strong need for public education and research to document the nuances and benefits of distributed water reuse.

Economics of Distributed Water Reuse

The economics of water and wastewater is not a simple matter and there are many financial influences that are difficult to fully assess. It is clearly recognized that via grants, low interest loans and other forms of public subsidies, U.S. residents generally do not pay the true cost of water and wastewater services and this creates undesirable consequences such as wasteful usage and overall lack of respect. Full cost pricing would change many behaviors and certainly influence future planning for water resource management such that water reuse would become more attractive.

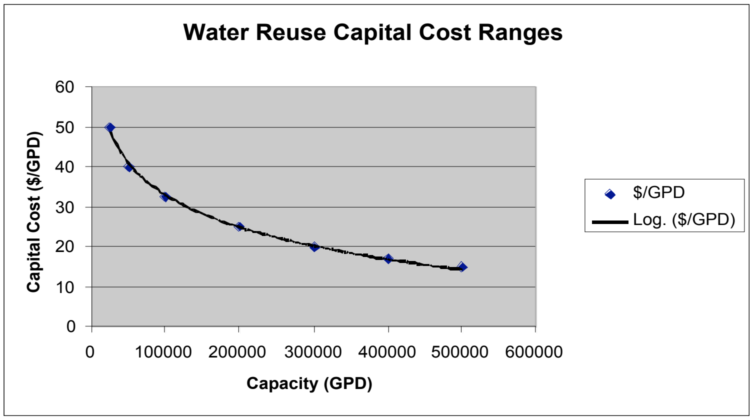
The water reuse systems described herein have all been built with private funds and the capital and operating costs are not directly subsidized in any way. New York City created an operating incentive in 2004 known as the Comprehensive Water Reuse Incentive Program which provides a 25% reduction in City water and sewer bills for buildings that realize a 25% reduction in water consumption by comparison to a base building. This creates a dual level customer charge system whereby there is a conventional rate and a reduced "Green Rate" for facilities that include direct water reuse (see Table 2). To my knowledge, this is the first indirect water reuse rate incentive in the U.S.

Table 2

New York City – 2007 Combined Water and Sewer Rates	Standard Rate	Green Incentive Rate
Current Rate	$6.99/1,000 gallons	$5.24/1,000 gallons
Proposed 18.5% increase	$8.28/1,000 gallons	$6.24/1,000 gallons

The capital cost of distributed water reuse systems varies with site conditions and size of the system. From experience, it appears that once the system reaches a size of approximately 500,000 gallons per day, it approximates the cost for municipal systems from a capital perspective at least in suburban and urban areas. In rural areas, the cost for conventional systems might be lower if the value of land is cheap. Figure 1 illustrates the variation in water reuse system capital cost as a function of system size.

Figure 1



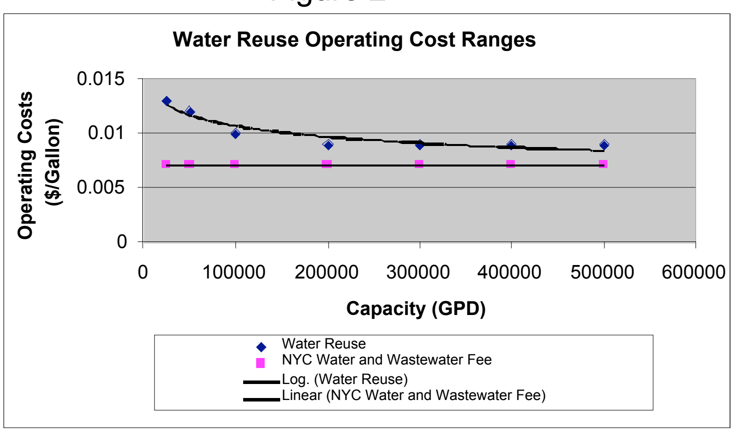
Capital Cost Range

- $50/GPD at 10,000 GPD
- $15/GPD at 500,000 GPD

(Based on current experience - specific site conditions would dictate actual costs)

From an operating perspective, costs also improve as system size increases, again with 500,000 GPD being the target operating size. Figure 2 illustrates the operating cost range based on New York City cost data.

Figure 2



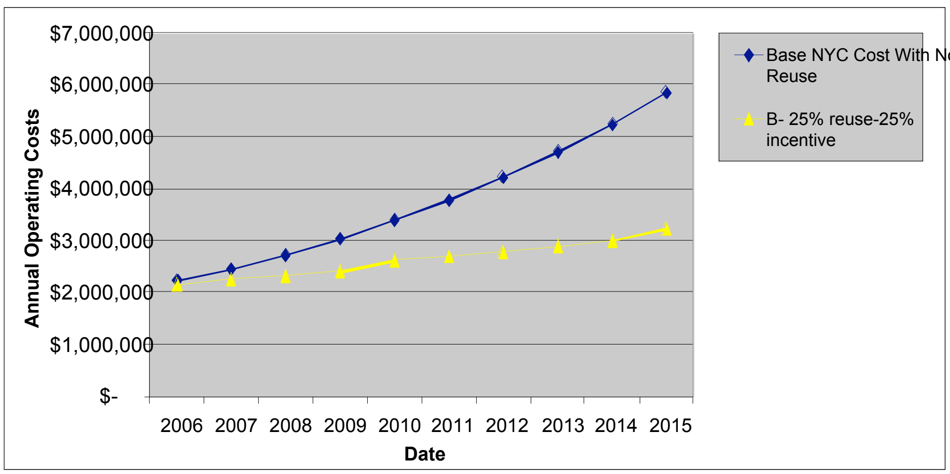
Operating Cost Range

- $0.013/Gallon at 25,000 GPD (not including 25% incentive)
- $0.009/Gallon at 400,000 GPD (not including 25% incentive)
- NYC = $0.007/Gallon W + WW (before recently proposed 18.5% incr ease for 2nd half of 2007 which would increase to $0.0083/gallon)

New York City water and sewer rates are just slightly above the mean for 25 large cities surveyed.[2] Atlanta ranks at the top with the highest rates and Chicago at the bottom with the lowest rates. The cost effectiveness of water reuse is therefore a local matter that must reflect local costs structure and conditions. With New York representing the mean, it provides a good test case for comparison with other areas around the U.S. Figure 3 illustrates the operating cost savings for approximately 10 million square feet of mixed office and residential use comparing the conventional approach vs. the water reuse approach. As indicated in this graph, water reuse in New York City is economical presently and becomes increasingly advantageous in the future. This would represent the optimum case under current New York City cost structure.

Figure 3

500,000 GPD Water Reuse Project



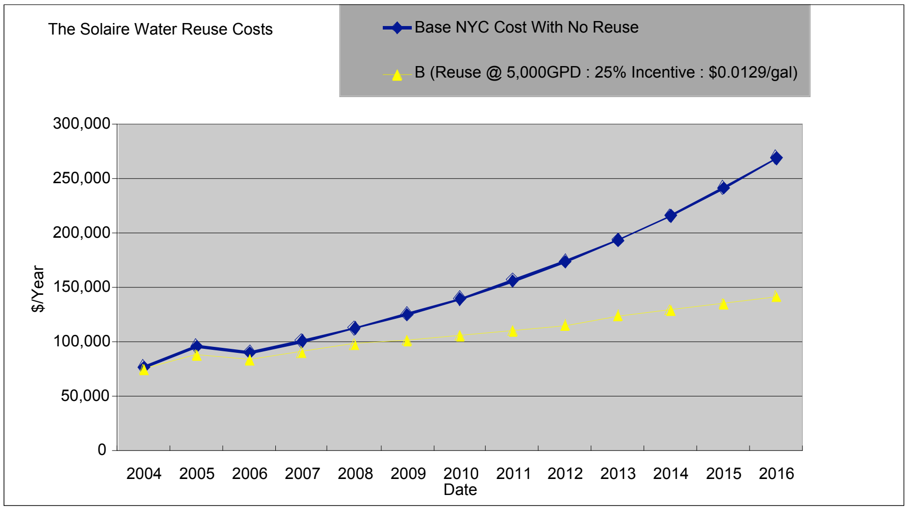
These figures represent 2007 New York City cost structure for 10 million square feet of mixed residential and commercial building space prior to propose d mid-year rate increase. Best case scenario

Figure 4 presents the same comparison for a smaller residential building that would include approximately 300 units. This cost information was derived from operating data at The Solaire, the first building of this nature. Ability to achieve higher levels of optimization would improve this cost picture somewhat, but even at this level, the long range picture illustrates that the distributed water reuse approach is more cost effective.

[2] Reference - New York City Department of Environmental Protection, New York City Water Board Public Information Regarding Water and Wastewater Rates, April 2007- commonly known as the Blue Book

Figure 4

25,000 GPD Residential Reuse Projects



These figures represent 2007 New York City cost structure for 30 0 unit residential building prior to proposed mid -year rate increase. Worst case scenario

From an operating cost perspective it has been demonstrated that water reuse in an urban setting such as New York City is cost effective in the short and long term. From a capital cost perspective, water reuse reduces the demands on both water supply and wastewater treatment infrastructure and the costs are reasonable when comparing the potential offset in future capital spending. The difficulty with the current structure in New York City is that developers are presently funding the capital costs themselves when in many cases they are not the recipients of the future operating savings. There is therefore no incentive for the developers to implement water reuse other then for the ability to achieve new green building standards. New York City is currently reviewing this inequity and is considering a capital incentive program that would compensate the developers accordingly. If this is implemented, the playing field between distributed water reuse and conventional centralized water and wastewater will be nearly leveled.

There are however, other considerations that reach beyond simple economics. Distributed water reuse systems offer an overall lower environmental impact so one would expect the costs to be greater, but at the moment there is no monetary consideration offered for this benefit.

Energy consumption is another area of water resource management that is not incorporated into this analysis. It is also now well recognized that there is a strong connection between energy consumption and water consumption, often referred to as the Energy/Water Nexus, which must be addressed in our future planning for both water and energy management. It is reported that U.S. citizens may indirectly use as much water turning on the lights and running electric appliances as they directly use flushing toilets and feeding water use appliances (see http://www.sandia.gov/energy-water/nexus_overview.htm). Direct water reuse offers many advantages from a water supply and environmental waste load perspective, but the energy aspects are not yet adequately quantified. The relationship between water and energy becomes even more complex as water reuse is incorporated into HVAC systems as a means of saving water, but at the same time improving energy efficiency.

According to the National Electric Testing Laboratory (NETL) 80% of the cost of treating, processing and pumping water is from energy (ref – Bajura 2002). Anecdotal information from existing distributed water reuse systems suggest that this electrical component is much lower (possibly as low as 40%) but there needs to be thorough investigation into the actual KW/gallon for both the conventional and water reuse approaches so that this relationship is well understood and incorporated into future water resource planning efforts.

Conclusion and Summary

Distributed water reuse systems must become a key aspect of our future water resource management programs because they offer so many advantages and only few drawbacks. Centralized systems will continue to serve as the backbone of water infrastructure for many years to come because so much infrastructure of this nature already exists, but future planning must include water reuse as a key component and must consider how these two approaches can be jointly optimized. Distributed water reuse systems offer a unique and compelling alternative to supplement and relieve the infrastructure that now exists and we must learn how to incorporate this approach most effectively. It will take a dedicated education, outreach and research effort for this to come to fruition.

Via water reuse, both distributed and centralized, we can accommodate a great deal of population growth and improved standard of living while providing better environmental protection. However, there exists a strong need to bring this new alternative to the public forefront and to fully thresh out the unique characteristics so as to build confidence and understanding.

Some key areas that deserve immediate attention are:

- Visible public demonstration projects of distributed water reuse that provide opportunities for education and research
- Research of the energy consumption aspects of water reuse vs. conventional approaches
- Research of methods for advancing water reuse into other nonpotable uses for improved efficiency
- Research of more advanced forms of reuse whereby nutrients are separated for nutrient reuse apart from water reuse