How Advanced Building Systems Can Offset Water Infrastructure Needs

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Abstract - Water infrastructure requirements will be reaching crisis proportions in the coming years. Increasing urban populations, drought conditions due to climate change, and increasing EPA rule limits for drinking water contaminants set the tone for diminishing water resources.

The American Society of Civil Engineer's 2013 Report Card for America's Infrastructure gives a grade of "D" for much of America's drinking water infrastructure. The report states that capital funding has not kept pace with the needs for water infrastructure and that state and local governments will continue to assume the bulk of investment requirements in the coming decades. If we think holistically, however, many of these water infrastructure needs can be offset by how we address the historic view of buildings' systems.

The current premise is that buildings should simply "plug-in" to existing water infrastructure. The expectation is that a new building connects to a municipal water main and clean water flows and that waste water is flushed away and disposed of at a municipal treatment plant. This belies our growing institutional knowledge of holistic building design and urban development. Rather than becoming a point source load on water infrastructure, buildings are capable of becoming water resource generators.

Precedent models for building based rainwater harvesting, reuse and treatment systems already exist, such as in the new San Francisco Public Utilities Commission building. This 277,500 square foot office building houses more than 900 employees, utilizes rainwater harvesting, and has an onsite "Living Machine" reclaiming and treating all of the building's wastewater to satisfy 100% of the water demand for the buildings low-flow toilets, urinals and irrigation. If we couple these advanced building systems with model water conservation ordinances such as Tucson's rainwater harvesting and gray water stub outs, we will rethink how buildings can actually offset water infrastructure needs.

Introduction

Climate Change and population growth are driving the Southwest toward the edge of water shortage. The US EPA states in its report on “Climate Impacts in the Southwest”:

“The climate of the Southwest is changing. Over the last century, the average annual temperature has increased about 1.5°F. Average annual temperature is projected to rise an additional 2.5-8°F by the end of the century. Warming in the Southwest is projected to be greatest in the summer.

Warming has already contributed to decreases in spring snowpack and Colorado River flows, which are an important source of water for the region. Future warming is projected to produce more severe droughts in the region, with further reductions in water supplies. Future water scarcity will be compounded by the region's rapid population growth, which is the highest in the nation.”[i]

It has already been noted that populations are increasingly urbanized. While in our rural and suburban areas agriculture and industry use the lion’s share of water, within the confines of our cities we must realize that the single largest usage of water usage growth is within our buildings.

Because of the link between water and energy usage, the US Department of Energy tracks water usage within the building sector. The statistics are startling:

“In 2005, water use in the buildings sector was estimated at 39.6 billion gallons per day, which is nearly 10% of total water use in the United States.

From 1985 to 2005, water use in the residential sector closely tracked population growth, while water use in the commercial sector grew almost twice as fast.

In 2005, between 27 billion and 39 billion kWh were consumed to pump, treat, distribute, and clean the water used in the buildings sector, accounting for 0.7 to 1% of net electricity generation.

In 2005, an estimated 410 billion gallons per day (bgd) of water were withdrawn for all uses in the United States. This total includes fresh and saline water from ground and surface sources. Domestic (residential) water use was the third largest water use category after thermoelectric power generation and irrigation, with an estimated 29.4 billion-gallons-per-day (bgd). Another 10.2 bgd were used in commercial buildings, for a total of 39.6 bgd in the buildings sector as a whole.

From 1985 to 2005, water use in the residential sector closely tracked population growth, while water use in the commercial sector grew almost twice as fast, as shown in the figure. All other water uses taken together were unchanged. As a result, total water use over those two decades increased less than 3%, while water use in the buildings sector increased 27%. The buildings sector's share of total water use increased from 7.8% to 9.7%."[ii]

With increasing urbanization, municipal water supply and treatment has struggled to keep pace but infrastructure needs and funding for expansion has fallen drastically behind. The last 10 years have seen regulatory changes that provided funding for corrections to outdated combined sanitary and storm water systems. These systems were "solved" by having sanitary systems take over existing infrastructure and stormwater being "daylighted" to surface flow. New sources of freshwater have been identified, but as indicated earlier, drought conditions are limiting availability. Furthermore, wastewater treatment systems are becoming overloaded as more and more building sources are brought on line.

Every 4 years, the American Society of Civil Engineers releases a Report Card for America's Infrastructure that depicts the condition and performance of the nation's infrastructure. In its 2013 report, ASCE gave the nation's wastewater treatment system a "D+":

"Wastewater infrastructure in the United States is aging, and investment is not able to keep up with the need. State and local governments incur approximately 98 percent of the capital investments annually to maintain and improve the infrastructure. In 2008, state and local governments estimated their total expenditures at $93 billion annually for wastewater and drinking water infrastructure.

The Congressional Budget Office, EPA, and other groups have estimated that it could take more than $300 billion to address the nation's sewage collection and treatment infrastructure needs over 20 years to keep our surface waters safe and clean. This is twice the current level of investment by all levels of our government. Congressional appropriations have declined over the five-year period 2008 to 2012, totaling only $10.5 billion—an average of $2.1 billion annually or $42 billion over 20 years."[iii]

The report further states that capital funding has not kept pace with the needs for water infrastructure and that state and local governments will continue to assume the bulk of investment requirements in the coming decades. If we think holistically, however, some of these water infrastructure needs can be offset by how we address the historic view of buildings' systems.

The current approach to design development is that buildings should simply "plug-in" to existing water infrastructure. The expectation is that a new building connects to a municipal water main and clean water flows and that waste water is flushed away and disposed of at a municipal treatment plant. This belies our growing institutional knowledge of holistic building design and urban development. Rather than becoming a point source load on water infrastructure, buildings are capable of becoming water resource generators.

The San Francisco Public Utilities Headquarters Building

Figure 1 The SFPU[iv]

While more than half of California is under the most severe level of drought for the first time since the federal government began issuing regular drought reports in the late 1990s, the City of San Francisco has been moving ahead with developing plans for implementing recycled water programs on multiple scales with centralized facilities, building scale incentives and district scale opportunities.

Seeking to set the example for water conservation and reuse, the San Francisco Public Utilities new headquarters facility was programmed to integrate building water systems from a building scale catchment and treatment perspective.

The 277,500 square-foot headquarters houses 950 employees and contains two non-potable water systems: a Living machine and a rainwater harvesting system.

“The Living Machine treats all of the building’s wastewater, up to 5,000 gallons per day, and then distributes the treated water for toilet flushing. The system reduces the building’s potable water consumption by approximately 65% and provides an annual potable offset of approximately 1,500,000 gallons. The system utilizes a series of diverse ecologically engineered wetlands, located in the sidewalks surrounding the headquarters and in the building lobby, to treat the wastewater. This unique treatment process blends function and aesthetics – the wastewater is treated to San Francisco Department of Public Health reuse standards while providing a high-profile pilot project for on-site water reuse.”[v]

While the water conservation and reuse function is truly remarkable, what is striking from the designer’s perspective is the streetscape associated and expressed by the Living Machine.

Figure 2 Living Machine at the SFPU[vi]

The planted strip that serves as a functional wetland separates the pedestrian walkways from vehicular corridors like a textbook image. This natural environment is not only serving as an aesthetic amenity and structural separation but also as a functional wastewater treatment system. The application is profound.

Making the Business Case for Integrated Natural Environments

While the SFPU has definitively shown how integrative natural systems can function. It does beg the question "how much did it cost?" The Living Machine, rainwater harvesting system, and their distribution piping cost approximately $1,000,000. The non-potable water systems increased the building's total construction costs of $146.5 million by less than 1%.

It is important to note that first costs belie the extensive benefits that are successive to its installation. Impacts at street level and increasing urban walkability come to mind at first, but internal to the building, additional benefits are quantifiable.

The desire of the human condition for some association with the natural environment has always been recognized. While in Rome with a group of students during the spring, I witnessed the sigh of relief when we escaped to the beach in Ostia, or when one student fell to his knees on the well-manicured lawn of the American Academy. However insightful, intuition falls short of explanation and is difficult to support. The academy of Architecture is well versed in drawing inference from precedent, theorizing by applying philosophical metaphor or seeking inspiration from allied arts and literature. Architects are steered toward Biophilia[vii] and other readings from Environmental Psychology, but these are reflective accounts or summaries of "successful" design precedent.

Architectural theorists also spend a great deal of time talking about "prospect – refuge" theory. Hildebrand is a great proponent of this attitude and uses it to establish a "sense of place" arguing that Hadrian was "drawn" to his Villa site in Tivoli. Searching for any sort of defensible science that supports this "prospect refuge" component led me to an article entitled "Methodological Characteristics of Research Testing Prospect–Refuge Theory: A Comparative Analysis"[viii]:

"Prospect–refuge theory proposes that environments which offer both outlook and enclosure provoke not only feelings of safety but also of spatially derived pleasure. This theory, which was adopted in environmental psychology, led Hildebrand to argue for its relevance to architecture and interior design. Hildebrand added further spatial qualities to this theory – including complexity and order – as key measures of the environmental aesthetics of space. Since that time, prospect–refuge theory has been associated with a growing number of works by renowned architects, but so far there is only limited empirical evidence to substantiate the theory. This [Dosen and Oswald's] paper analyses and compares the methods used in 30 quantitative attempts to examine the validity of prospect–refuge theory. Its purpose is not to review the findings of these studies, but to examine their methodological bases and biases and comment on their relevance for future research in this field."

The article cites 30 separate quantitative attempts to examine the theory. One of those cited "Is Love for Green in Our Genes? A Critical Analysis of Evolutionary Assumptions in Restorative Environments Research"[ix]. This paper provides the necessary empirical research to make the business case for integrating ecological systems:

"Within the field of restorative environments research, it is commonly assumed that restorative responses, triggered by exposure to natural elements and settings, are ultimately adaptive traits originating from our species' long evolutionary history in natural environments. The aim of this article is to critically investigate the viability of this evolutionary view on restoration. In doing so, we specifically focus on Stress Recovery Theory (SRT), as this theoretical framework has most extensively elaborated on the supposed evolutionary origins of restoration."

Furthermore, the article "Architectural Lessons from Environmental Psychology: The Case of Biophilic Architecture"[x] states:

"A review of findings from the field of environmental psychology shows that humans are aesthetically attracted to natural contents and to particular landscape configurations. These features are also found to have positive effects on human functioning and can reduce stress. However, opportunities for contact with these elements are reduced in modern urban life. It is argued how this evolution can have subtle but nontrivial adverse effects on psychological and physiological well-being. These can be countered by integrating key features of natural contents and structural landscape features in the built environment. Several practical proposals are discussed, ranging from literal imitations of natural objects (such as plants) to the use of nature's fractal geometry in an architectural context."

Cognitive Psychology presents the case for the persistence of desire for integrated natural environments (i.e. why do we find tree lined streets so eminently walkable). The studies indicate that they were conducted under varying conditions and measured stress using capacitive skin resistance and blood cortisol levels which is typical in the medical community. Subjects were given stressful testing tasks or were in hospital environments experiencing stressful situations, and then exposed, sometimes to just a picture, to a natural environment. It is important to note that the pictures/scenes were of more savannah style, not dark forests or wilderness areas. These "tree shelter framing the plain" savannah-like environments are much like the suggested designs of our walkable streets.

It is important to draw this connection and point out that the success of the business case for the USGBC LEED standard rests on increased sales, increased test scores AND increased productivity. With increased productivity there are economic gains that support the investment in the system and/or methodologies that produce them. This is the economic model that has been used to make the case for sustainability and LEED for the past 20 years.

The American Psychology Association publishes a Fact Sheet “Psychologically Healthy Workplace Program Fact Sheet: By the Numbers” with the following data:

> “• Sixty-nine percent of employees report that work is a significant source of stress and 41% say they typically feel tense or stressed out during the workday (American Psychological Association, 2009).
>
> • Fifty-one percent of employees said they were less productive at work as a result of stress (American Psychological Association, 2009).
>
> • Fifty-two percent of employees report that they have considered or made a decision about their career such as looking for a new job, declining a promotion or leaving a job based on workplace stress (American Psychological Association, 2007).
>
> • In 2001, the median number of days away from work as a result of anxiety, stress, and related disorders was 25 – substantially greater than the median of 6 for all nonfatal injury and illness cases (Bureau of Labor Statistics, 2001).
>
> • In a study of a large, multi-employer, multi-site employee population, healthcare expenditures for employees with high levels of stress were 46% higher than those for employees who did not have high levels of stress (Goetzel et al., 1998).
>
> • Job stress is estimated to cost U.S. industry more than $300 billion a year in absenteeism, turnover, diminished productivity and medical, legal and insurance costs (Rosch, 2001).”[xi]

Obviously the dollar value associated with even minor gains in stress reduction would lead investors to support studies utilizing restorative environments which can be provided by the integrated natural environments.

Conclusion

Climate change is inevitable. Responding to increasing population and urbanization is being met at a global scale. In the US, California is not the only state to respond to the water issue. “Recognizing that Tucson, as a desert community, faces a drastic need for water conservation in order to prevent drought conditions, the City of Tucson has passed an ordinance that makes it easy for homeowners to reuse their gray water for landscaping. Gray water is recycled water from clothes washers, bathtubs, showers, and bathroom sinks. Beginning June 1, 2010, all new construction of single-family homes and duplexes in Tucson will be required to include plumbing to distribute gray water for outdoor irrigation.”[xii]

Rethinking how a building interacts with its environment and how its systems function with regard to water systems can expand the definition of how buildings can contribute to the urban experience. Instead of looking at landscape/streetscape as external to the building, we should be looking at the water equation and meld the systems as a holistic expression of symbiosis as the building seeks to contribute and regenerate the environment instead of just taking from or existing in it.

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[i] "Climate Impacts in the Southwest | Climate Change | US EPA," accessed September 13, 2014, http://www.epa.gov/climatechange/impacts-adaptation/southwest.html.

[ii] "Buildings Energy Data Book," accessed September 13, 2014, http://buildingsdatabook.eren.doe.gov/ChapterIntro8.aspx.

[iii] "ASCE | 2013 Report Card for America's Infrastructure | Wastewater: Overview," accessed September 13, 2014, http://www.infrastructurereportcard.org/a/#p/wastewater/overview.

[iv] "Showimage.aspx (JPEG Image, 300 × 450 Pixels)," accessed April 13, 2015, http://sfwater.org/modules/showimage.aspx?imageid=1501.

[v] "ShowDocument.aspx," accessed September 13, 2014, http://www.sfwater.org/Modules/ShowDocument.aspx?documentID=5499.

[vi] Ibid.

[vii] Edward Wilson, *Biophilia*, Reprint edition (Harvard University Press, 1986).

[viii] Annemarie S. Dosen and Michael J. Ostwald, "Methodological Characteristics of Research Testing Prospect–refuge Theory: A Comparative Analysis," *Architectural Science Review* 56, no. 3 (June 25, 2013): 232–41, doi:10.1080/00038628.2013.809689.

[ix] Yannick Joye and Agnes van den Berg, "Is Love for Green in Our Genes? A Critical Analysis of Evolutionary Assumptions in Restorative Environments Research," *Urban Forestry & Urban Greening* 10, no. 4 (2011): 261–68, doi:10.1016/j.ufug.2011.07.004.

[x] Yannick Joye, "Architectural Lessons from Environmental Psychology: The Case of Biophilic Architecture.," *Review of General Psychology* 11, no. 4 (December 2007): 305–28.

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[xii] "Tucson - Residential Gray Water," accessed September 13, 2014, http://www.greencitiescalifornia.org/best-practices/water/tucson_residential-gray-water.html.