HydroScape: Applying New Decentralized Water System Practices to Commercial Building Adaptations within Colorado

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Abstract

This research addresses the water scarcity crisis through infrastructure decentralization, the process of treating and managing water on site, using innovative water systems and management. American cities currently distribute water using centralized water management infrastructure, this is an inefficient process in which water is stored and treated in a single location to serve a large community using a pipe network. This system is outdated, lacks adaptability, and has unreliable water purification processes. By exploring the integration of decentralized water filtration systems, my research despsite Colorado's policy limitations will show how these changes can address pressing environmental issues such as drought, water pollution, and excessive water consumption. I will examine and compare case studies of platinum scored new construction and retrofit/adaptive reuse buildings, then leverage guided frameworks provided by Leadership in Energy and Environmental Design (LEED) and the Living Building Challenge (LBC). My strategies mitigate the environmental climate crisis by spreading awareness on water scarcity issues, while simultaneously introducing decentralized approaches to water management solutions.

Using retention and reclamation systems and conservation technologies has proven that water loss and overconsumption have been reduced in urban buildings by up to 40%. However, there are strict policies on water reclamation and retention regarding treatment and collection of non-potable water on-site, directed towards Western States. Within Colorado these policies are highly enforced due to its role in the chain of water distribution, as well as its high precipitation rates as shown by National Oceanic and Atmospheric Association (NOAA). As long as I stay within guidelines it is possible to integrate a decentralized water system in Colorado. There are numerous case studies building precedents that I analyze to determine successful systems technologies and water management processes like: Reverse Osmosis, UV Purification, and Biomaterial Filtration/Low Impact Development (LID). These water processes provide opportunities for urban renewal and reduce dependency on outdated water infrastructures via safe and legal water filtration practices.

My goal is to design a system for Colorado reyling on decentralized water processes specifically for adaptive reuse initiatives while maintaining urban preservation goals. However, this leads to the possibility of system compatibility issues and may require significant retrofits. The overall balance between building performance and structural preservation is critical, as both are essential for the successful implementation of my sustainable water management suggestions. Despite these challenges, advancing urban efficiency while emphasizing the critical role of innovation in water management remains both achievable and essential.

Key Words: Water Conservation, Water Scarcity, Water Filtration Systems, Decentralized Water Filtration, Centralized Water Management Infrastructure, Urban Improvement, Adaptive Reuse

Introduction

Water scarcity and quality have become prominent issues facing modern society. The need for accessible, clean, and safe water is putting pressure on existing water infrastructure, further exacerbated by increasing urbanization and population growth. Traditional centralized urban water management is a method that involves treating and distributing water from a central location to serve large populations through an extensive network of pipes and infrastructure (Living Future, 2019). While centralized urban water management can be effective to an extent, it is often unable to address the complex challenges of water purity, energy consumption, and urban growth adaptability. My research addresses these issues by exploring a decentralized water system integration approach, which involves treating water and wastewater on-site, and developing a sustainable, efficient water supply within existing commercial buildings. Adopting this approach represents a more sustainable long-term strategy, as adaptive reuse is intended to extends a building's operational lifespan by updating it to better address communities' economic and social needs rather than tearing down and building new structures (American Institution of Architects, 2023).

My goal is to raise awareness of water scarcity and quality issues through the examination of decentralized systems within case studies of both new construction and adaptive reuse buildings. Through deeper research into the strengths and weaknesses of decentralized water systems, I identified opportunities to implement innovative designs found in new constructions towards adaptive reuse buildings, moving beyond basic retrofits to incorporate system integration. These findings inform practical adjustments to building policies related to adaptive reuse initiatives, while continuing to promoting more sustainable practices.

The primary focus of my research is the ntegration of on site or decentralized water treatment and management systems within adaptive reuse contexts, evaluated through their effectiveness in new building construction. I also examine which building system strategies most efficiently support water conservation and reuse. I then briefly discuss system technologies and processes, which, when applied effectively at a commercial level, could lead to developments in energy conservation, water safety, and overall building efficiency within Colorado. The main research question I will address is: How have water filtration systems been integrated into net-zero strategies, and in what ways have frameworks like Leadership of Energy and Environmental Design (LEED) and the Living Building Challenge (LBC) reinforced these water conservation approaches through updated guidelines? As a result of answering this primary question, I will also be comparing what water systems are more efficient and sustainable for non-residential buildings within the United States Western Region, specifically Colorado. These questions are based on the growing recognition that current urban water infrastructures are no longer equipped to address the challenges of extreme climates (WWF, 2021), increasing urbanization (Living Future, 2019), and natural resource depletion (Petruzzello, 2025).

Research to date shows that implemented innovative decentralized systems are found in notable LEED-certified projects (Younus, 2017), but others are only applied at a small scale or in experimental contexts (Sitzenfreia & Raucha, 2014) showing that there is much more to be explored regarding their broader application in adaptable settings. This research addresses how these technologies reveal significant opportunities for innovation in reuse situations and future water management. Although still in its preliminary phase, this research suggests that the combination of filtration technologies and adaptive building designs could not only solve immediate water safety problems but could also serve as an updated model for future building regulations

This research is compelling in its potential to contribute to both the fields of adaptive reuse and water resource management. By addressing a gap in the literature through the examination of water systems, this research supports water conservation and resource management. This is made possible through the refinement of water system design in existing commercial buildings, an area that remains underexplored and often overlooked. These discoveries could influence the normalization of new practices and encourage the adaptation of new water management processes. By integrating decentralized systems across Colorado and leveraging the influence of organizations like LEED and Living Buildings Challenge (LBD), there is a significant opportunity to enhance western water infrastructure. All while fostering greater awareness of the growing challenges of water scarcity and the need for sustainable solutions.

Through my research analysis, I will also develop a project providing practical design solutions to pressing environmental issues through education on increasing water scarcity, deteriorating water quality, and energy demands of existing treatment processes. My preliminary model for a commercially sustainable eco-building meets LEED and LBC standards while incorporating my findings on hydrophilic water filtration systems. My model will demonstrate how the system could function as a self-sufficient solution to the water challenges of modern cities like Denver.

This research begins to raise important questions about how water is treated as a fundamental right and how outdated infrastructures contribute to ongoing inequities in water distribution, particularly in disadvantaged communities. Implementing decentralized systems in urban commercial buildings has the potential to not only improve water quality but also narrow the gap of inequitable access. I also have revealed the Regional Policies regarding water distribution, reclamation, retention, and building adaptations. of my research and design process. By legally integrating these systems into adaptive building designs, we can create a model where local, self-sufficient water filtration can be immediately redistributed. These innovations can mitigate the unequal impacts of water scarcity, especially in regions most affected by extreme climates or outdated and unsafe infrastructure.

The strength of these approaches relies on the different focuses and potential the research has to offer. It addresses simultaneously the immediate need for better long-term water filtration systems through newer technologies and the adaptation and preservation of commercial buildings. My research provides a foundation for further research into how these systems can be deployed, especially as cities face increasing pressures from resource depletion, increasing populations, and extreme climates. By identifying critical environmental and preservation issues through the lens of decentralized technologies and their potential application in commercial buildings. The questions I have raised about the efficiency and adaptability of these systems will inform the rest of my research. Ultimately, contributing to the development of a new generation of energy-efficient self-sufficient water management systems that can address current water challenges being faced in the 21st century.

Literature Review

Environmental and Climate Adaptation Challenges:

Water Scarcity and Safety

Water scarcity is an escalating concern across the United States, particularly in southwestern regions where the climate is predominantly arid or semi-arid. The growing urbanization in these areas is increasing water demands, significantly straining already limited resources (World Wildlife Foundation, 2021). Recognizing this dilemma, the U.S. Department of State is progressively implementing federal laws at the state level to address this crisis. These initiatives have led to the creation of regional "environmental hubs" that prioritize maintaining the health and distribution of freshwater systems while ensuring their ecological integrity and sustainability (Postel &Richter 2000). Such measures conserve both the quantity, quality, and timing of water flows that freshwater ecosystems need to sustain their essential functions. However, despite efforts to manage water through traditional engineering projects like dams, these solutions often fail to preserve vital ecological processes and underscore the complexity of balancing water use with environmental health (Postel & Richter 2000). Other organizations like the World Wildlife Foundation in partnership with the World Water Council began to spread awareness of these issues to enhance the understanding of the global water crisis. They push to "[help] businesses take the next step from assessing their risks to building a comprehensive water stewardship strategy" (WWF, 2021). Addressing water scarcity in a broader commercialized way is essential for the argument of integrating sustainable water practices. This then can be applied to commercial buildings to contribute to a more resilient future, rather than presenting a band-aid solution to our currently struggling water infrastructure.

Colorado Standards for Commercial Buildings and Water Conservation

According to the Regional Standards for Water Conservation in the U.S., water conservation varies significantly and is often shaped by local water resource availability. Specifically within Colorado and the broader Western and Midwestern regions, where drought and poor water quality present consistent challenges. Policies have been implemented to manage water distribution and water reclamation in order to serve as preventative measures to maintain sustainable water supply systems and prevent local water depletion during seasonal drought. However, these policies sometimes place limits on water conservation practices; for instance, in Colorado, rainwater harvesting operations require, “annual approval from [Division of Water Resources] DWR through a Substitute Water Supply Plan (SWSP) or permanent approval of an Augmentation Plan in Water Court,” (DWR, 2019). This is in conjunction with Colorado HB09-1129 which explains that the use of these and their use of rainwater systems, limited tocan and only will be utilized ingin approved stormwater collection processes and in circumstances where water is used to irrigate vegetation. . An alternative to rainwater collection methods is greywater/non-potable water systems. After being approved by the Board of Environmental Health “greywater for toilet and urinal flushing must be dyed … [to] be visibly distinct from potable water,” (Board of Environmental Health, 2016). When considering current Colorado law, these systems would be preferred to rainwater collection as they are compatible with municipal water standards.

Impact of Climate Change on Water Consumption

Climate change has substantial direct and indirect impacts on water consumption within buildings, with rising temperatures increasing demands for water usage for cooling systems and landscaping needs. These effects are emphasized by climate-induced water scarcity, which requires more rigorous conservation measures in commercial buildings. The increasing scarcity of potable water poses serious challenges, as "many countries around the world face severe shortages and compromised water quality," and even regions that were once rich in freshwater are now at risk due to "the impacts of climate change, highly unsustainable water use patterns, and the continued drawdown of major aquifers," (World Health Organization 2006). When addressing relentless consumption patterns there are other accompanying concerns such as environmental pollution and water safety, as "the continuous growth in the consumption of natural resources… has been followed by the intensification of the environmental pollution of water, air, and soil," (World Health Organization 2006). Serious and prolonged droughts, particularly in the southwestern United States, and conflicts over water rights in the West, indicate that the privileges of water supplies are disappearing. In an article called Charting a Future for the Colorado River, Colorado is devising new ways to spread awareness for potential negative impacts caused by water scarcity. "The Southwest is seeing a historic mega-drought and the Colorado River's flows have declined by 20% over the last century. Looking ahead, scientists predict that the river's flows could shrink by as much as 31% by 2050," (The Nature Conservation, 2021), a situation that is further stressed by anticipated population growth and the impacts of evident climate changes.

Current Technologies and Methods:

Centralized Water Filtration Infrastructure & Methods

A centralized water filtration system, as defined by the District of British Columbia's Ministry of Health Guidelines (2017), "treats water in a central location and then distributes water via a dedicated distribution network." This is common practice in many urban areas because a "centralized water treatment system can treat large volumes of water at high rates to accommodate all residential, business, and industrial uses," (BC Ministry of Health, 2017). When used in commercial buildings, these methods often rely on mechanical and chemical processes to remove impurities. Recent technological advancements have enabled scaled-down versions of centralized infrastructure, allowing for efficient on-site water treatment and reducing reliance on government maintenance and long-distance transportation. Much of the existing infrastructure that supports centralized systems is outdated, often leading to inefficiencies and potential health or safety concerns. Many of these systems across the U.S."are now approaching over 100 years of age," and their replacement will require substantial investments potentially "billions of dollars... every year for the next 50 years" (Living Future, 2019). The outdated nature of this infrastructure highlights its limitations, as it often demands significant energy and maintenance, constraining its sustainability. Centralized systems that rely on "long-distance delivery of water causes considerable energy consumption and high capital cost," dedicating roughly 80-90% to transportation. Alternatively, the "decentralized system has been gaining increasing attention as a better solution," (Daio, 2021). Although municipal systems were designed to prevent public outbreaks and mitigate flooding, they now prolong and inhibit efforts for innovation. "Our centralized, big-pipe infrastructure relies on an industrial model of specialization and economies," and is "typically resource and energy intensive in [its] transport and treatment of water and pose[s] serious social, environmental and economic risks for urban American communities," (Sisolak & Spataro, 2011). The review of these traditional systems shows the necessity of transitioning to more efficient and modern water technologies that promote sustainability and resilience in commercial projects.

Low Impact Development

Low-impact development (LID) is an innovative approach to stormwater management that mimics natural processes, helps reduce runoff, and enhances groundwater recharge (EPA, 2012). This approach to architectural design was adopted in the 1990s influencing many urban projects found in Denver, and new progressive water policies. By utilizing elements such as permeable paving, rainwater gardens, green roofs, and biofilters in urban planning, LID reduces the burden on traditional water infrastructure while improving water quality. These practices emphasize the capture and filtering of stormwater and how it minimizes the "impacts from [urban] development and the need for ongoing or long-term maintenance… [and] focuses on natural solutions," (EPA, 2012). Incorporating LID into water conservation efforts aligns with many LEED and LBC requirements, as well as Denver city policies instated by the DWR. By applying LID principles to new developments and renovations, communities can reduce water consumption, and protect natural waterways which is key for Colorado as it is a major contributor to Western water distribution.

Decentralized Water Filtration Methods

Advances in filtration technology present compelling alternatives to traditional water filtration methods. These modern systems are designed to enable enhanced filtration with reduced both unnecessary water and energy consumption. Decentralized hydrophilic filtration aligns with LEED & Living Building Challenge (LBC) standards regarding water efficiency through the promotion of practices such as water recycling and reduced consumption. Newly developed water system programmaticaly designed for commercial buildings often are more efficient and are used to serve specific purposes. For instance, RO systems are used as a purification system this process occurs when water moves in a reverse direction and is pressurized then strains through a membrane removing all impurities/particles (Kucera, 2023). However, RO systems have high energy requirements and a water recovery rate of 50-60% (NewSchool of Architecture and Design, 2019) because the system is so efficient it's ideally used within industrial complexes or laboratories. UV Purification also known as UV Sanitation is a disinfection method that utilizes UV light to inactivate harmful microorganisms in water by damaging their DNA, rendering them unable to reproduce. In decentralized water filtration systems, which operate independently from centralized municipal treatment facilities, UV purification serves as a critical component for ensuring safe potable water (Oguma, 2023). Ceramic filters are an effective and natural means of filtration, "us[ing] tiny pores on a ceramic surface to filter bacteria and sediment out of [potable] drinking water," (Woodard, 2023). Undoubtedly integrating any of these methods, influences a shift towards more sustainable water management in commercial buildings, which aligns with distributed systems that "allow or are open to allowing the inclusion of decentralized systems" for future sustainability (Sisolak & Spataro 2011). These systems in tandem with greywater recycling techniques which are, "considered to be the most economical and feasible solution" (De Gisi et al., 2015) can lead to the adaptation of decentralized systems in all urban commercial buildings.

Comparative Analysis

Comparisons between centralized and decentralized water filtration approaches are common, especially within communities that are exposed to, "the perception of water scarcity… critical facilitating factor that conditions public attitudes toward alternative water systems. This is especially evident in countries with water restrictions" (Gómez-Román et al., 2020). Conducting these analyses highlights viable solutions for achieving net-zero water goals in commercial buildings, focusing on the advantages of on-site hydrophilic treatment over traditional off-site processing plants. Centralized water filtration methods, because they are ill-maintained and outdated, have the potential to cause public epidemics or large-scale system malfunctions (Living Future, 2019). Additionally, centralized systems, such as those used for large-scale water recycling, often involve complex and energy-intensive processes. For instance, Orange County, California, hosts the world's largest water recycling facility, which processes 130 million gallons of blackwater daily through a rigorous three-step purification (Robbins, 2023). While this system is quite robust and is designed to protect public health and provide large-scale water solutions, it remains resource-intensive and poses environmental and economic risks for urban areas (Sisolak & Spataro, 2011). Studies have also proven that, in contrast, "[decentralized] systems are much easier to manage than traditional centralized plants, which are larger and need constant professional supervision" (Gómez-Román et al., 2020). Decentralized system approaches contain on-site treatment practices that enhance water retention and filtration with less energy consumption, as well as promote the reuse of non-potable water through greywater plumbing solutions. Gómez-Román et al. "suggest[s] that without significant investments in the adoption of alternative sources and treatment practices, these [unrestricted] regions are likely to face serious problems maintaining an adequate water supply." Implementing decentralized and greywater recycling solutions in commercial buildings could greatly improve water sustainability and support the shift towards net-zero water goals, paving the way for more resilient infrastructure that is adaptable to future climate-related challenges.

Water Efficiency Design Standards and Conservation Strategies:

LEED Standards for Water Efficiency

Leadership in Energy and Environmental Design (LEED) standard certification process provides a comprehensive framework for enhancing water efficiency in commercial buildings, emphasizing the integration of water-saving fixtures, recycling systems, and rainwater harvesting. These guidelines are instrumental in promoting sustainable water practices and helping buildings meet rigorous environmental goals. A major aspect of the LEED v4.1 Guidebook is its focus on reducing potable water use, particularly for building sewage conveyance, by at least 50%. This can be achieved through the use of water-conserving fixtures, such as water-efficient toilets and urinals, or by utilizing non-potable water sources like captured rainwater, recycled greywater, or on-site or municipally treated wastewater (LEED, 2023). The incorporation of these water-saving measures is a critical part of LEED-certified buildings' efforts to mitigate the environmental impact of water consumption.

LEED emphasizes the importance of site-specific water management by promoting strategies that replicate natural hydrology and water balance. This ensures that the water management system is designed to "reduce runoff volume and improve water quality by replicating the natural hydrology and water balance of the site, based on historical conditions and undeveloped ecosystems in the region" (LEED, 2023). This approach not only minimizes the risk of flooding in frontline communities downstream but also helps maintain ecological balance in urban environments. In addition to addressing runoff, LEED encourages further reductions in fixture water use, urging buildings to achieve savings beyond the required baseline for indoor water use. These savings can be enhanced by incorporating alternative water sources, with the inclusion of necessary fixtures and fittings tailored to the specific needs of building occupants (LEED, 2023). By adhering to these guidelines, LEED-certified buildings serve as models for how commercial properties can make significant strides in water conservation, integrating sustainable systems that promote long-term environmental and economic benefits.

Living Building Challenge Water "Petal"

The Living Building Challenge (LBC), similar to LEED, sets progressive water goals, including net-zero water, commercial water harvesting, and on-site greywater reuse. LBC-certified buildings achieve these goals by implementing new building methods, advocating for decentralization, and encouraging district-level solutions that are "appropriately scaled, elegant, and efficient" (Living Future, 2019). These water systems are designed to meet the needs of the building while ensuring a fair and equitable allocation of resources among surrounding communities, both upstream and downstream. In order to be recognized there is a step-by-step framework:

1. *Evaluate the current code landscape.*
2. *Design a compliant system.*
3. *Get the project permitted.*

I05 Net Positive Water, the municipal standard for LBC, "requires Living Buildings to derive water input from resources on site and to manage water output on site," by utilizing technologies and strategies that are widely available (Living Future, 2019). They also emphasize resilience, supporting both rapid and slow changes to ensure long-term sustainability and preserve the health of both human and ecological communities (Living Future, 2019). The program was first launched by the Cascadia Green Building Council in 2006, the LBC framework has gained significant traction, leading to the formation of the International Living Future Institute to manage its certification process (Mattar et al., 2023). By adopting similar strategies, commercial buildings can reduce water dependence and align with the sustainable water management practices promoted by the LBC.

Certification Systems & Net Zero Water Goals

Certification systems through LEED and LBC offer structured frameworks to improve water efficiency and reduce the environmental impact of buildings. These systems promote strategies such as water conservation practices, incorporating alternative filtration methods, closing water distribution loops, and on-site water treatment. These strategies are critical to mitigating the pressures on limited water resources amid growing populations and water scarcity. Noted in Sustainable and Resilient Building Design, the "consumption of fresh water also means pressuring the water resources that, in the light of growing population and climate change, form a huge social and ecological problem." Also, as commercial, industrial, and other developments expand, their reliance on municipal potable water supplies increases, intensifying competition for these finite resources (LEED, 2023). There is the possibility to apply these principles to cities like Denver through the navigation of municipal policies, along with LEED & LBC regulations in order to avoid them. Guidelines for Denver Water Conservation issue that the use of non-potable and excess storm-water run-off is permitted. This aligns with both environmental frameworks set by LEED & LBC. Utilizing permissible decentralized systems/on-site water management in combination with water water-conscious fixtures in Denver buildings. These buildings can then play a significant role in promoting water sustainability and reshaping urban design to reduce environmental impact and improve resource conservation.

Adaptive Reuse and Retrofit Approach:

Retrofitting New Systems

Retrofitting existing buildings with advanced water systems, such as greywater recycling and rainwater harvesting, can significantly reduce water use and enhance sustainability. While this approach presents many benefits, it also poses challenges, especially in integrating new systems into older structures. Renovating these buildings requires careful consideration of eco-friendly, energy-efficient materials and systems, which can help minimize environmental impact and improve energy efficiency. This is emphasized in Strategies and Practices of Renovating Old Buildings and Urban Renewal, which highlights the need to use renewable materials, recycled resources, and high-performance insulation to reduce pollution. Additionally, retrofitting can lead to substantial water savings by incorporating water-efficient appliances and recycling systems. Retrofitting Cities with Decentralized Energy, Transportation, and Water notes that such systems enable the reuse of stormwater and wastewater for irrigation, toilet flushing, and cooling, evidently reducing overall water demand in commercial buildings.

This shift towards decentralized systems not only improves sustainability but also helps meet higher environmental standards in urban developments.

LEED Standards for Adaptive Reuse

LEED provides specific guidelines for adaptive reuse, emphasizing water conservation and efficiency in renovated buildings. This practice is regarded as a key sustainability strategy, as it allows for the reuse of existing materials, reduces demolition waste, and conserves energy that has already been expended in the original construction (Preservation Green Lab, 2011). When properly executed, adaptive reuse can preserve the historical legacy of a building while minimizing new carbon emissions, which aligns with LEED's goals for environmental sustainability. One notable advantage of adaptive reuse is its incorporation of vernacular architecture, which uses locally sourced materials and construction practices that reflect the region's culture and history, further enhancing a building's connection to its community. The Adaptive Reuse Scorecard provided by LEED helps developers evaluate the viability of such projects, focusing on aspects like building systems, sustainability, and overall development potential. This includes reusing significant portions of the existing building "typically up to 50% of one building or 20% of overall building stock" which optimizes resource use and supports water conservation efforts in the process. Water efficiency for existing buildings is very similar to that of new construction, except with an emphasis on obvious water conservation projections and the use of innovative plumbing fixtures (LEED, 2023). The O+M: Existing Buildings Guidelines-v4.1 states that buildings attempting to achieve significant water efficiency improvements, "[must] have permanently installed sub-meters that measure total potable water use for any fixtures or fittings in the project scope… [or] a pro-rate water use, using occupancy and base building water use over twelve consecutive months," (LEED, 2023). These measures allow LEED to track and monitor the improvements in water efficiency and an overall internal water consumption reduction. Having both building preservation and water fixture improvements proves adaptive reuse practices are preferable practices of architectural sustainability.

Existing Site Limitations and Advancements

Adapting to older buildings to improve water efficiency often presents robust challenges, including space constraints, outdated infrastructure, and regulatory hurdles. These difficulties are addressed through innovative design strategies that adapt to the unique needs of each building type. Policies and regulations play a critical role in facilitating these retrofits by providing clear standards and guidelines for the renovation of old buildings, ensuring that safety and quality are maintained while meeting sustainability goals (Li, 2023). However, the complexity of older buildings, particularly those in historical districts, often raises renovation costs and requires specialized knowledge and technology, which can strain financial resources and delay projects. Issues like outdated engineering systems and a lack of skilled professionals can exaggerate these challenges. To overcome these barriers, new technologies such as water quality sensors and in-line testing are being integrated into retrofitted systems to ensure proper water management, while updates to building codes are necessary to support these advancements in water efficiency (Crosson, 2020). These solutions not only make water sustainability more feasible in older buildings but also contribute to a broader transition toward more efficient and resiliently sustainable urban infrastructures.

Research Strategies:

Policy Challenges

Implementing water-saving technologies in commercial buildings is often hindered by regulatory and policy constraints. For example, in Colorado, rainwater harvesting is traditionally illegal due to the Doctrine of Prior Appropriation, which considers rainwater a tributary water source, potentially affecting senior water rights (Lytle Water Solutions, 2024). As water scarcity becomes more of an issue, state legislatures are beginning to consider mandates or incentives to encourage water-saving technologies and practices in both residential and commercial sectors. While the concept of "conservation" varies by region, it generally includes policies aimed at reducing water waste and promoting more sustainable water use, such as the integration of water-efficient fixtures or the collection of water data for comparative analysis (Lytle Water Solutions, 2024). The choice of greywater treatment systems for buildings must be tailored to local conditions, accounting for legislation, the socio-economic environment, and the specific needs of the building occupants (De Gisi et al., 2015). The City of Denver is introducing more progressive policies as it becomes more aware of the impacts of water scarcity. For example, the Rainwater Harvesting Pilot Projects introduced by Denver's Department of Natural Resources in 2019 illustrate that although the state cannot commercially retain water in cisterns, stormwater may be temporarily retained to benefit onsite irrigation and non-potable reuse (Department of Natural Resources, 2019). As decentralized filtration systems become more prevalent in architectural practice cities like Denver will be more receptive to municipal changes and rely less on outdated centralized infrastructures. However, these current regulatory frameworks, though restrictive, also present opportunities for policymakers to adapt and support the broader adoption of water-efficient technologies in commercial buildings.

LEED v4.1 BD+C
Project Checklist

Project Name:
Date:

Y	?	N			
			Credit	Integrative Process	1

Y	?	N			
0	0	0		**Location and Transportation**	**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site and Equitable Development	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Electric Vehicles	1
0	0	0		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
0	0	0		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Optimize Process Water Use	2
			Credit	Water Metering	1
0	0	0		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Grid Harmonization	2
			Credit	Renewable Energy	5
			Credit	Enhanced Refrigerant Management	1

Y	?	N			
0	0	0		**Materials and Resources**	**13**
Y			Prereq	Storage and Collection of Recyclables	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Environmental Product Declarations	2
			Credit	Sourcing of Raw Materials	2
			Credit	Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2
0	0	0		**Indoor Environmental Quality**	**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1
0	0	0		**Innovation**	**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0		**Regional Priority**	**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	0	0		**TOTALS** Possible Points:	**110**

.ed: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80

LEED v4.1 for Operations & Maintenance: Existing Buildings
Scorecard

Y	?	N			
0	0	0		**Location and Transportation**	**14**
6			Prereq	Transportation Performance	14
0	0	0		**Sustainable Sites**	**4**
			Credit	Rainwater Management	1
			Credit	Heat Island Reduction	1
			Credit	Light Pollution Reduction	1
			Credit	Site Management	1
0	0	0		**Water Efficiency**	**15**
6			Prereq	Water Performance	15
0	0	0		**Energy and Atmosphere**	**35**
Y			Prereq	Energy Efficiency Best Management Practices	Required
Y			Prereq	Fundamental Refrigerant Management	Required
13			Prereq	Energy Performance	33
			Credit	Enhanced Refrigerant Management	1
			Credit	Grid Harmonization	1
0	0	0		**Materials and Resources**	**9**
Y			Prereq	Purchasing Policy	Required
Y			Prereq	Facility Maintenance and Renovations Policy	Required
3			Prereq	Waste Performance	8
			Credit	Purchasing	1

Y	?	N			
0	0	0		**Indoor Environmental Quality**	**22**
Y			Prereq	Minimum Indoor Air Quality	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
Y			Prereq	Green Cleaning Policy	Required
8			Prereq	Indoor Environmental Quality Performance	20
			Credit	Green Cleaning	1
			Credit	Integrated Pest Management	1
0	0	0		**Innovation**	**1**
			Credit	Innovation	1
0	0	0		**TOTALS** Possible Points:	**100**

Certified: 40-49 points, **Silver:** 50-59 points, **Gold:** 60-79 points, **Platinum** 80+ points

Research Methods

My research argument focuses primarily on issues related to inefficiencies within centralized filtration systems and water scarcity. I aim to provide a thorough understanding of water efficiency in urban Colorado commercial buildings and make practical recommendations to develop decentralized water management systems further. My research compares, analyzes, and evaluates qualitative data on water conservation technologies and their potential to improve water sustainability in these commercial buildings. I identify both the strengths and limitations of current filtration systems while exploring how innovative and decentralized approaches address these inefficiencies. To support these findings, I analyze case studies of both new construction and adaptive reuse buildings that are certified for Leadership in Energy and Environmental Design (LEED) and recognized by the Living Building Challenges (LBC).

The LEED certification is a structured and rigorous measure of environmental performance and is a rating system to assess sustainability based on updated guidelines. By reviewing scorecards and other documentation, I evaluate how these buildings meet water sustainability goals, specifically through filtration, irrigation, and water management systems. This comparison provides insight into effective practices and highlights common inefficiencies that impact the sustainability of commercial buildings. In conjunction with LEED frameworks, I will also be identifying buildings recognized by LBC. Similar to LEED, LBC's certification guidelines promote regenerative building design, focusing on net-positive water systems for harvesting, treating, and reusing water on-site. This aligns with my argument by emphasizing decentralized water management.

To support my analysis, I developed a systematic database that categorizes LEED-certified (all Platinum) and LBC-recognized buildings based on region, building programs, certification levels, and water efficiency methodologies. This database allows me to identify intersections where water conservation technologies can be aligned with building practices, adaptive reuse strategies, and global efforts to improve water quality and combat climate issues. By comparing the sustainability scores of these buildings, I reveal various patterns in water use, filtration efficiency, and system adaptability. This structured approach highlights where current centralized systems are not meeting sustainability standards and how future decentralized designs can achieve greater efficiency.

My research relies on a variety of sources, including case studies supported by LEED-certified and LBC-recognized buildings, and technical qualities of water filtration technologies. These sources provide a comprehensive overview of the performance of filtration systems in real-world applications and inform potential improvements to building adaptations. In addition, I incorporate insights from discussions with architects who have experience with the sustainable design and construction of LEED-certified buildings. These discussions provide valuable perspectives on the iterative processes involved in integrating advanced water management systems. By also analyzing professional blueprints and technical drawings, I identify discrepancies that do not meet LEED or LBC environmental certification standards, providing opportunities for further refinement.

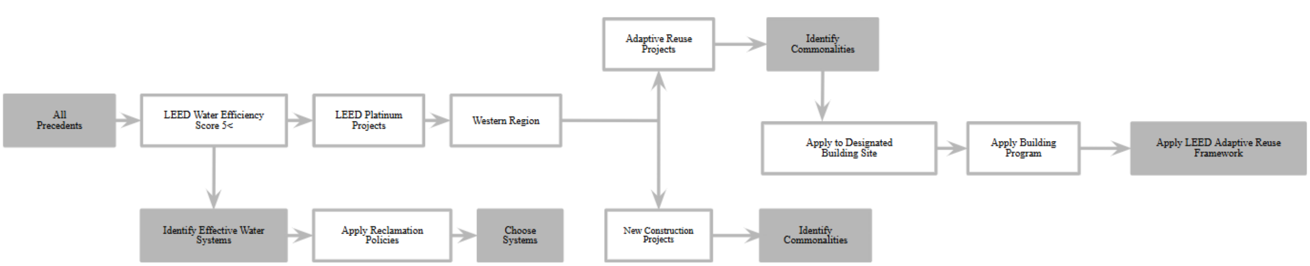
I incorporate this research with my proposal for system retrofitting and adaptive reuse application following the identified building precedents and Colorado Policy. I choose to focus on adaptive reuse because of its repurposing qualities, and its ability to reduce the environmental impact of new construction. This approach is particularly relevant in urban Colorado, where many commercial buildings face challenges related to outdated water management systems. By aligning adaptive reuse practices with decentralized water systems, my research identifies opportunities to retrofit these structures through building analysis, design iteration, and application.

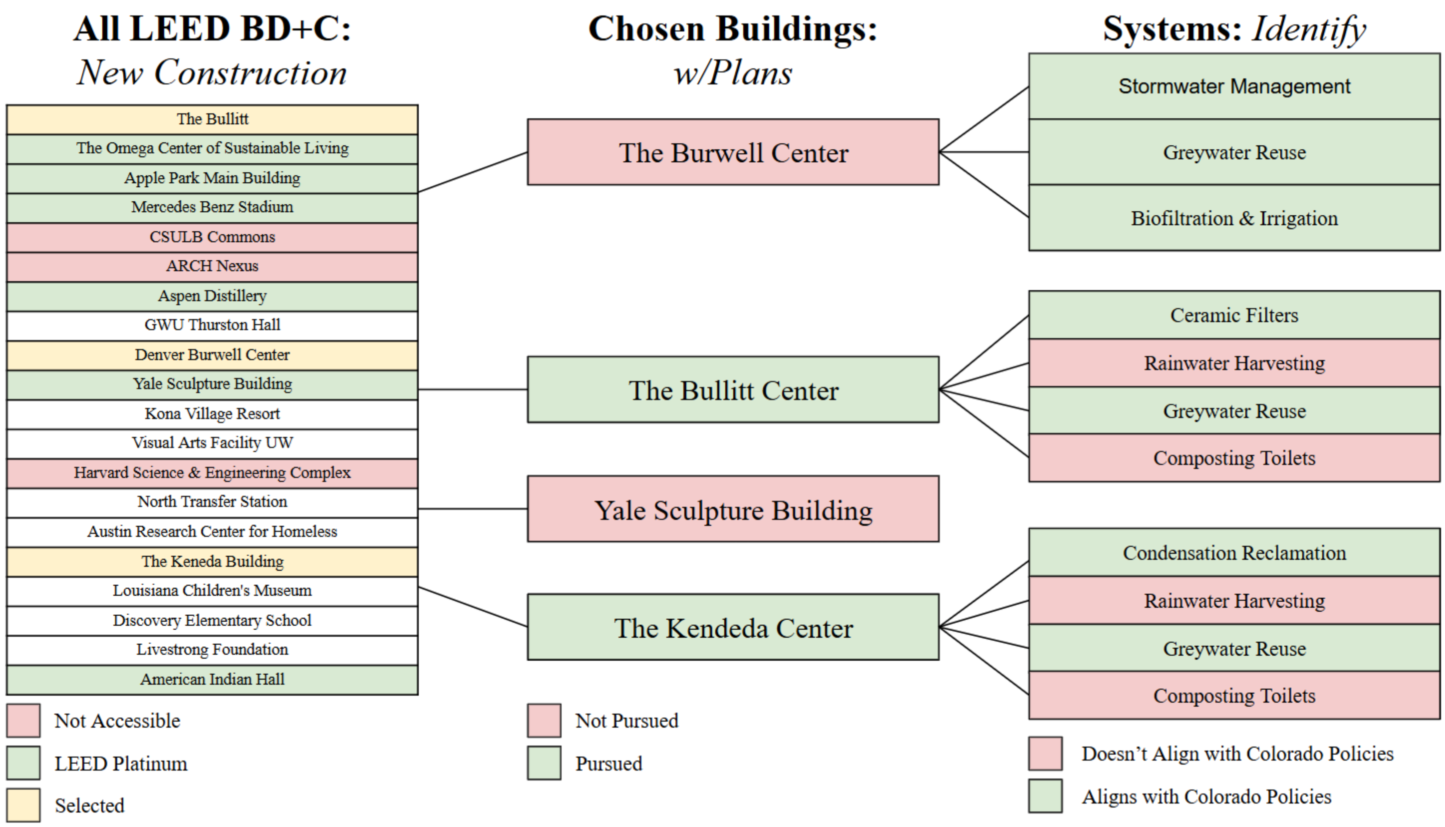
Ultimately, my goal is to expound upon the discourse on sustainable water management by demonstrating how integrating decentralized system designs can improve the efficiency and adaptability of commercial buildings. By addressing water scarcity and quality issues through adaptive reuse strategies and innovative filtration technologies, this research aims to encourage more sustainable and resilient urban infrastructures.

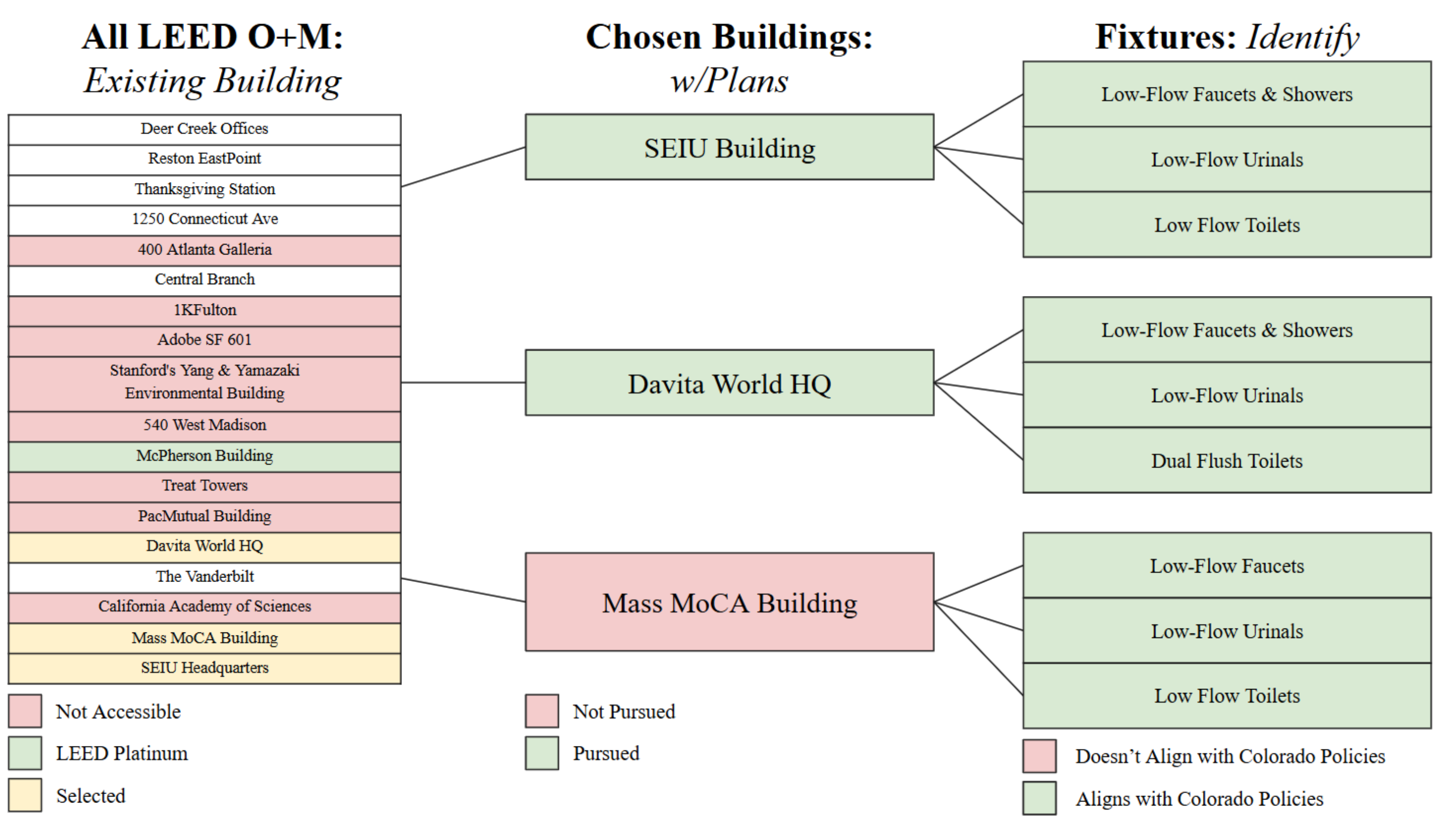
It is necessary to adopt water conservation technologies as it will enable the decentralization of the city of Denver's centralized water system infrastructure. My research shows that many of these systems are already in place across the United States, and have shown significant advantages over traditional filtration infrastructure. Currently, there is a unique opportunity for water decentralization within adaptive reuse practices through innovative system integration. I turned to case studies, and industry guidelines indicating performance success, water recovery rates, and program compatibility. For example, process analysis of water conservation systems reveals their potential to outperform traditional systems in terms of water recovery and energy use, particularly when retrofitted into existing buildings. This claim is supported by the growing demand for water efficiency requirements, demonstrating that such technologies improve filtration efficiency, reduce resource consumption, and align with Leadership in Energy and Environmental Design (LEED) standards, which promote sustainability in green building design. To substantiate this argument, I analyze case-study evidence of current water filtration methods, and I identify conservation system process programming and design, while also considering the implications of their application in adaptive reuse contexts.

Selection Process

By employing a comparative analytical framework of precedent buildings, I was able to assess the advantages and disadvantages of decentralized water systems through selected case studies of LEED-certified new construction and adaptive reuse projects. My research predominantly focuses on system analysis through new construction because of the lack of data surrounding adaptive reuse and entire plumbing system integration, with a couple of exceptions. Regardless, after compiling a data chart of various LEED Certified projects I was able to identify through these case studies what design components would be beneficial to compare and further analyze. Each chosen building, after careful scorecard evaluation (Water Efficiency 5< points), contributes to my research and understanding of system placement, system process, and system programming. Each building demonstrates unique characteristics and building programs contributing to the selection of particular water filtration system processes.




All LEED BD+C:
New Construction
The Bullitt
The Omega Center of Sustainable Living
Apple Park Main Building
Mercedes Benz Stadium
CSULB Commons
ARCH Nexus
Aspen Distillery
GWU Thurston Hall
Denver Burwell Center
Yale Sculpture Building
Kona Village Resort
Visual Arts Facility UW
Harvard Science & Engineering Complex
North Transfer Station
Austin Research Center for Homeless
The Keneda Building
Louisiana Children's Museum
Discovery Elementary School
Livestrong Foundation
American Indian Hall
Not Accessible
LEED Platinum
Selected
Chosen Buildings:
w/Plans
The Burwell Center
The Bullitt Center
Yale Sculpture Building
The Kendeda Center
Not Pursued
Pursued
Systems: Identify
Stormwater Management
Greywater Reuse
Biofiltration & Irrigation
Ceramic Filters
Rainwater Harvesting
Greywater Reuse
Composting Toilets
Condensation Reclamation
Rainwater Harvesting
Greywater Reuse
Composting Toilets
Doesn't Align with Colorado Policies
Aligns with Colorado Policies


All LEED O+M:
Existing Building
Deer Creek Offices
Reston EastPoint
Thanksgiving Station
1250 Connecticut Ave
400 Atlanta Galleria
Central Branch
1KFulton
Adobe SF 601
Stanford's Yang & Yamazaki Environmental Building
540 West Madison
McPherson Building
Treat Towers
PacMutual Building
Davita World HQ
The Vanderbilt
California Academy of Sciences
Mass MoCA Building
SEIU Headquarters
Not Accessible
LEED Platinum
Selected
Chosen Buildings:
w/Plans
SEIU Building
Davita World HQ
Mass MoCA Building
Not Pursued
Pursued
Fixtures: Identify
Low-Flow Faucets & Showers
Low-Flow Urinals
Low Flow Toilets
Low-Flow Faucets & Showers
Low-Flow Urinals
Dual Flush Toilets
Low-Flow Faucets
Low-Flow Urinals
Low Flow Toilets
Doesn't Align with Colorado Policies
Aligns with Colorado Policies

Research Data and Argumentation

Building Data Analysis

I further analyze these selected buildings as case studies: the Bullitt Center, the Kendeda Building,the SEIU Headquarters and the DaVita World Headquarters. By examining their water systems, fixtures, and programmatic these buildings can demonstrate innovative water conservation technologies and systems designed to significantly reduce water consumption while adhering to its state's municipal laws striving towards environmental sustainability. My research shows that these buildings predominantly rely on advanced filtration and rainwater harvesting, low-flow plumbing fixtures, and low impact design approaches. By exploring each building's unique approaches, this analysis highlights the impact of decentralized design in addressing water scarcity and promoting adaptable long-term water infrastructure solutions.

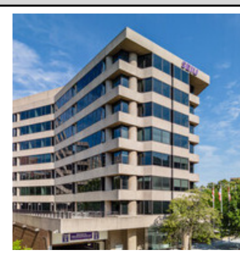
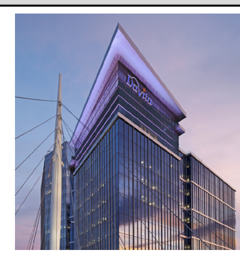
1. **Bullitt Center:** Located in Seattle, the Bullitt Center is famous for its sustainable design, earning LEED Platinum certification shortly after its completion in 2011. As an administrative building, it serves as a model for water efficiency and environmental stewardship, integrating innovative systems like rainwater harvesting, greywater reuse, and composting toilets. Designed to meet the standards of the Living Building Challenge, the Bullitt Center exemplifies how commercial buildings can operate with minimal environmental impact, achieving net-zero water usage.
2. **Kendeda Building:** Located on Georgia Tech's campus in Atlanta, the Kendeda Building for Innovative Sustainable Design is a flagship project in regenerative architecture. Completed in 2019, it achieved full certification under the Living Building Challenge by incorporating net-zero energy and water systems. The building uses rainwater harvesting, composting toilets, and greywater systems to meet its water needs, while also supporting a rooftop garden and pollinator habitat. Serving as a multi-use educational facility, the Kendeda Building demonstrates how institutional spaces can embody equity, ecology, and sustainability at every scale.
3. **SEIU Headquarters:** Located at 1800 Massachusetts Avenue in Washington, D.C., the SEIU Headquarters underwent a comprehensive retrofit to align with sustainable building standards, including LEED certification. As part of its modernization, the building prioritized water conservation through the replacement of outdated plumbing fixtures with high-efficiency alternatives such as low-flow toilets, faucets, and showerheads. These retrofits significantly reduced overall water consumption without compromising functionality. By upgrading its internal systems rather than rebuilding, the SEIU Headquarters showcases how existing buildings can be transformed into high-performing, resource-efficient spaces through targeted interventions.
4. **Davita World Headquarters:** Located in downtown Denver, the DaVita World Headquarters reflects a strong commitment to sustainability through thoughtful system upgrades and LEED Platinum certification. The building incorporates extensive water-saving strategies, including the replacement of standard plumbing fixtures with ultra-low-flow toilets, faucets, and showerheads. These improvements, alongside a smart irrigation system and water-efficient cooling towers, contribute to an overall 45% reduction in water use compared to baseline standards. By integrating conservation-focused retrofits into a high-occupancy commercial setting, DaVita demonstrates how corporate headquarters can significantly minimize their environmental footprint while maintaining performance and comfort.

Building System Analysis

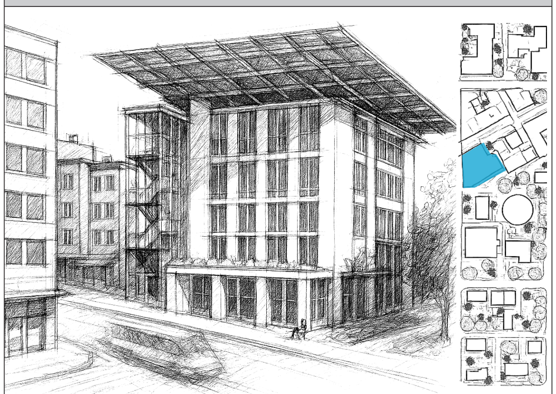
Through careful observation there is a noticeable pattern that each building plan highlights a unified plumbing system. The filtration systems are resourceful and placed on the lower levels to make the best use of space and energy. Consolidating the plumbing system in the heart of the building ensures easy access and maximizes square footage. This design choice means all areas can be serviced with ease, maintaining an organized and efficient layout. Additionally, integrating rainwater harvesting or stormwater management is a natural fit. Water collected from the roof flows down to the filtration systems, where it can be purified or pumped. The combination of these design strategies not only saves energy but also maximizes the building's functional design.

The four buildings highlights distinct patterns in net water consumption is tied directly to whether the project was new construction or adaptive reuse. The new construction projects, Bullitt Center and the Kendeda Building, demonstrate significantly lower net water consumption rates. This is largely due to the freedom to fully integrate decentralized systems. These buildings leveraged innovations like rainwater harvesting, greywater reuse, and composting toilets without being constrained by legacy infrastructure, allowing them to achieve net-zero water performance more effectively.

In contrast, adaptive reuse projects, SEIU Headquarters and the DaVita World Headquarters, faced structural limitations that confined their ability to implement comprehensive water systems. Retrofitting existing plumbing, accommodating older layouts, and meeting pre-existing code requirements restricted the scale and type of water conservation strategies that could be employed. As a result, while both adaptive reuse projects achieved meaningful reductions in water use compared to conventional baselines, their net consumption remains higher than that of the new construction examples.

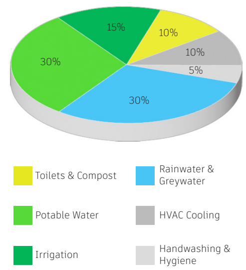
	The Bullitt Center	Kendeda Building	SEIU Headquarters	Davita Headquarters
Perspective				
Building Type	New Construction	New Construction	Retrofitting	Retrofitting
Square Footage	52,000 sq ft	58,800 sq ft	217,543 sq ft	195,000 sq ft
Building Program	Office & Administration	School Administration & Laboratory	Office & Administration	Office & Laboratory
Year Built	2011	2019	1978	2016
Region, State, City	**West**, Washington, Seattle	**East,** Atlanta, Georgia	**East,** Washington DC	**West**, Colorado, Denver
LEED Certification	**LEED BD+C**: New Construction - LEED v4	**LEED BD+C**: New Construction - LEED v4	**LEED O+M**: Existing Buildingsv3 - LEED 2009	**LEED O+M**: Existing Buildingsv3 - LEED 2010
Water Efficiency Score	**N/A ~ 11/11**	**11/11**	**13/14**	**11/14**
Filtration System	Ceramic Filter, Rainwater Harvesting, Greywater Reuse, UV Sanitation	Ceramic Filter, Rainwater Harvesting, Greywater Reuse, UV Sanitation	N/A	N/A
Additional Fixtures	Waterless Urinals, Low-Flow Fixtures, Composting Toilets, Drought Tolerance	Waterless Urinals, Low-Flow Fixtures, Composting Toilets, Drought Tolerance	Low-Flow Fixtures, Dual Flush Toilets, Drought Tolerance	Low-Flow Fixtures, Dual Flush Toilets, Drought Tolerance
Amount of Water Conserved	Reducing water consumption by **95%** **(52K gallons per year)**	Reducing water consumption by **80%** **(50K gallons per year)**	Reducing water consumption by **33%** **(4.7 gallons per year)**	Reducing water consumption by **46%** **(1.2M gallons per year)**

THE BULLITT CENTER - *Seattle, Washington*
New Construction



NET ZERO BREAKDOWN

Achieved by a closed-loop system that mimics natural hydrological cycles. Rainwater is captured on the roof and stored, then filtered and treated for potable use throughout the building. After use, greywater from sinks and showers is treated through a combination of constructed wetlands, evapotranspiration, and infiltration, allowing it to safely return to the ground. Composting toilets eliminate the need for traditional blackwater systems. This avoids relying on municipal water or sewer infrastructure, creating a self-sustaining water cycle and models regenerative urban design.

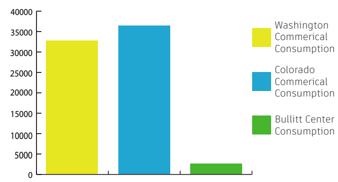


OCCUPANCY LEVELS

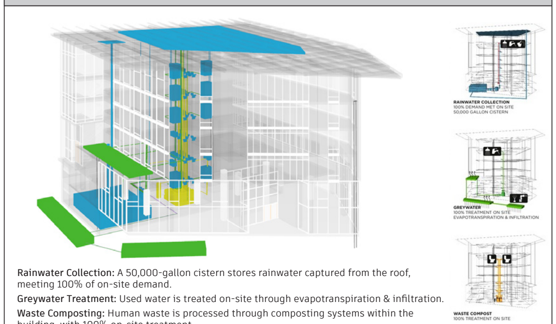
The Bullitt Center in Seattle has a design occupancy of approximately 170 people, with an expected occupancy of 125 employees. As of August 2023, the building's occupancy rate was reported at 78%, with tenants' staff present about 60% of the time on average. This indicates that around 133 individuals are employed by tenants in the building, with approximately 80 individuals present on a typical day.

Bullitt Center Occupancy & Consumption	
Number of Occupants/Employees	Annual Water Consumption (gallons)
10	18250
25	45625
50	91250
75	136875
100	182500
150	273750
200	365000

ANNUAL WATER CONSUMPTION COMPARISON



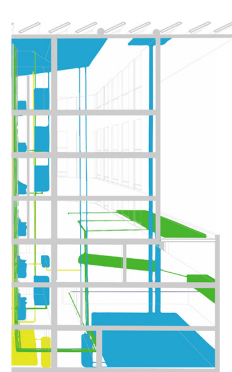
NET ZERO SYSTEMS STUDY
Rainwater - Greywater Reuse - Composting



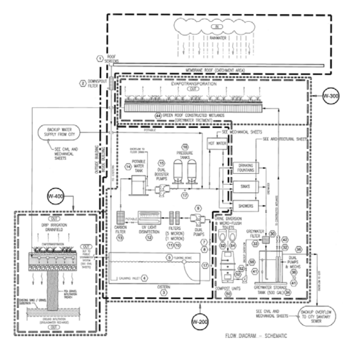
Rainwater Collection: A 50,000-gallon cistern stores rainwater captured from the roof, meeting 100% of on-site demand.

Greywater Treatment: Used water is treated on-site through evapotranspiration & infiltration.

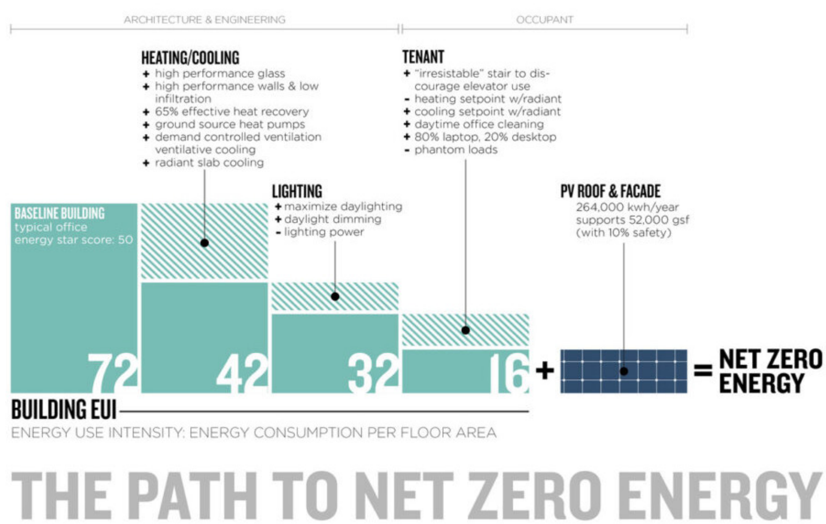
Waste Composting: Human waste is processed through composting systems within the building, with 100% on-site treatment.



SYSTEMS SECTION

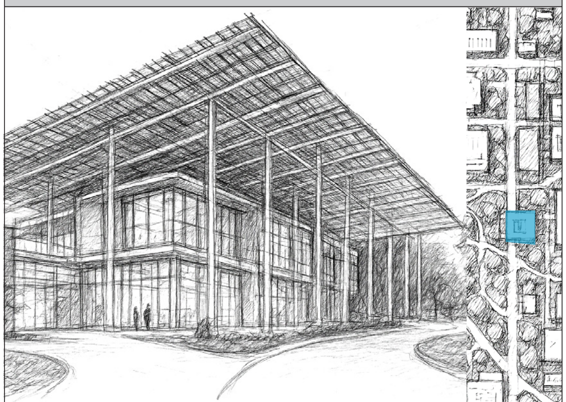


SYSTEMS CYCLE DIAGRAM



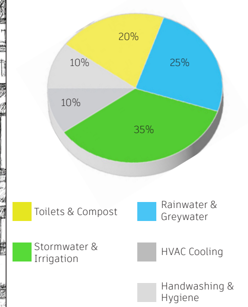
The Bullitt Center is LEED Platinum certified and is widely recognized for its exemplary performance in water conservation. While the official LEED scorecard is not publicly accessible, published reports confirm it achieved a total of 84 points, placing it well above the 80 point threshold for Platinum certification. Based on its documented water strategies including rainwater harvesting, composting toilets, and greywater reuse, it is estimated that the building earned 10 out of the possible 11 points in the Water Efficiency category.

KENDEDA BUILDING - *Atlanta, Georgia*
New Construction



NET ZERO BREAKDOWN

The Kendeda Building achieves net-zero water by harvesting rainwater for all potable needs, using composting toilets to eliminate blackwater, and treating greywater on-site through natural systems. These strategies create a closed-loop system that operates independently from municipal water and sewer infrastructure.

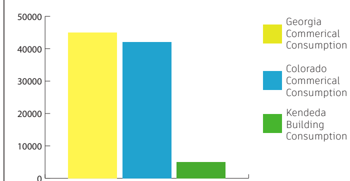


OCCUPANCY LEVELS

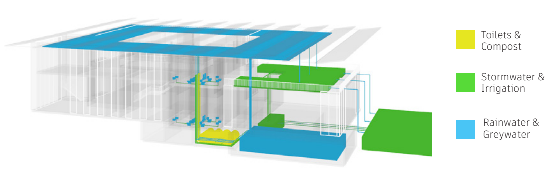
In the Kendeda Building, occupancy directly influences the building's net-zero water performance. Designed to operate efficiently at full capacity, its rainwater harvesting, composting toilets, and greywater treatment systems scale with use. As occupancy increases, these systems are fully engaged, showcasing the building's ability to maintain regenerative water use without relying on municipal supply—proving that high performance can be sustained even with dense daily use.

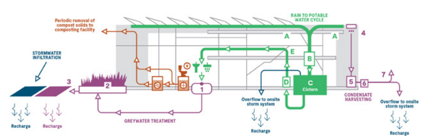
Kendeda Occpuancy & Consumption (Annually)	
Estimated Occupants	Annual Water Consumption (gallons)
50	91250
75	136875
100	182500
125	228125
150	273750
175	319375
200	365000

ANNUAL WATER CONSUMPTION COMPARISON

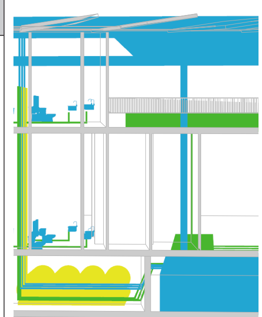


NET ZERO SYSTEMS STUDY
Rainwater Collection - Greywater Reuse - Composting





The Kendeda Building treats rainwater for drinking, reuses greywater for flushing, and processes black water through composting toilets to achieve net-positive water performance.



SYSTEMS SECTION

The Kendeda Building uses a decentralized treatment system that filters greywater through a series of mechanical and biological processes. After initial filtration, the water is treated using UV disinfection and fine-particle filters to meet potable standards. This system, combined with constructed wetlands and infiltration beds, allows the building to safely recycle water on-site. Its compact, energy-efficient design showcases an innovative approach to closed-loop water reuse in commercial buildings.

SYSTEMS CYCLE IMAGE

WATER EFFICIENCY		AWARDED: 11 / 11
Prereq	Outdoor water use reduction	0 / 0
Prereq	Indoor water use reduction	0 / 0
Prereq	Building-level water metering	0 / 0
Credit	Cooling tower water use	2 / 2
Credit	Water metering	1 / 1
Credit	Outdoor water use reduction	2 / 2
Credit	Indoor water use reduction	6 / 6

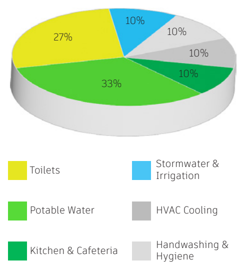
The Kendeda Building for Innovative Sustainable Design is LEED Platinum certified and exemplifies high-performance environmental design. According to its LEED v4 scorecard, the building earned 89 out of 110 possible points, including a perfect score of 11 out of 11 in the Water Efficiency category. This was achieved through strategies such as indoor and outdoor water use reduction, cooling tower water efficiency, and comprehensive water metering. The building also received full points in Sustainable Sites, Innovation, Regional Priority, and Integrative Process, reflecting a holistic approach to sustainability. These achievements position the Kendeda Building as a model for regenerative design in higher education and commercial construction.

DAVITA HEADQUARTERS - *Denver, Colorado*

Retrofit

CONSUMPTION BREAKDOWN

DaVita's water use is concentrated in restrooms and general potable needs, with smaller amounts for HVAC, handwashing, irrigation, and kitchen use. Through low-flow fixtures and greywater systems, the building reduces overall consumption by 45%, supporting its LEED Platinum goals and sustainable operations. This strategic distribution prioritizes efficiency in high-use areas. It also sets a benchmark for water-conscious design in large-scale commercial buildings.

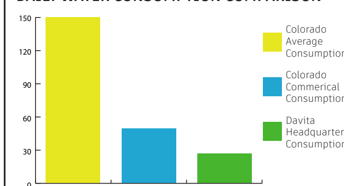


OCCUPANCY LEVELS

DaVita's average occupancy of around 3,000 employees results in a significantly lower per-person water use compared to the Colorado state average. With conservation measures in place, the building uses approximately 27.5 gallons per person per day, totaling about 10,037 gallons annually per employee—well below the Colorado per capita average of 150 gallons per day. This reflects a 45% reduction from typical commercial usage. DaVita's performance highlights how intentional design and technology can dramatically cut water use in high-occupancy buildings.

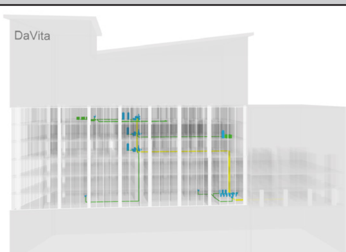
Davita Occupancy & Consumption (Annually)		
Estimated Occupants	Baseline Annual Water Use (gallons)	Estimated Actual Use (gallons)
1500	27429750	26229750
1750	32001375	30801375
2000	36573000	35373000
2250	41144625	39944625
2500	45716250	44516250

DAILY WATER CONSUMPTION COMPARISON



FIXTURE REPLACEMENT

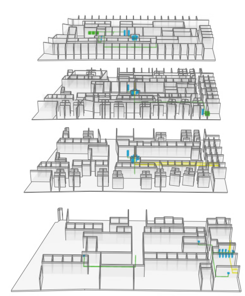
Low Flow Fixtures - Greywater Collection



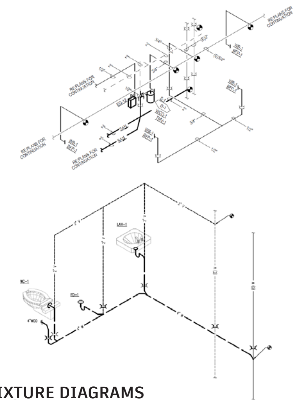
Plumbing Fixtures: These represent standard water outlets such as sinks, urinals, and showers distributed throughout the building.

Black Water System: This system captures wastewater from toilets and other heavily contaminated sources, directing it to municipal treatment.

Greywater System: Water from sinks, showers, and other lightly used sources is collected separately and redirected for reuse.



RENOVATED SECTIONS

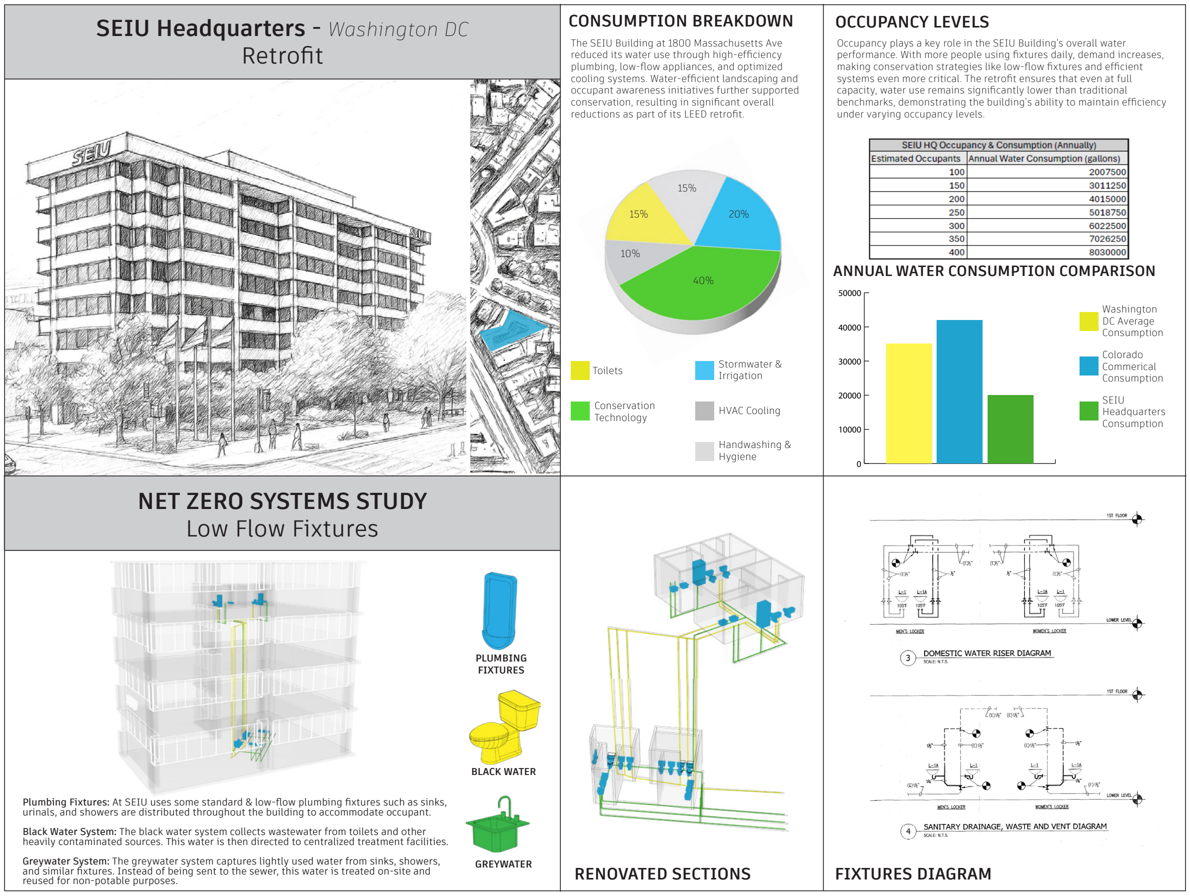


FIXTURE DIAGRAMS

WATER EFFICIENCY — AWARDED: 11 / 14

WEp1	Minimum indoor plumbing fixture and fitting efficiency	REQUIRED
WEc1	Water performance measurement	2 / 2
WEc2	Additional indoor plumbing fixture and fitting efficiency	5 / 5
WEc3	Water efficient landscaping	3 / 5
WEc4	Cooling tower water Mgmt	1 / 2

The DaVita World Headquarters in Denver, Colorado is LEED Platinum certified under the LEED v2009 Operations and Maintenance (O+M) for Existing Buildings rating system. According to its official scorecard, the building earned 85 out of a possible 110 points. It performed particularly well in categories such as Sustainable Sites (23 out of 26), Water Efficiency (11 out of 14), and Indoor Environmental Quality (12 out of 15). In the Water Efficiency category, the building achieved full points for indoor plumbing fixture upgrades and water performance measurement, along with credits for efficient landscaping and cooling tower water management. These scores reflect DaVita's commitment to long-term resource conservation, occupant health, and sustainable building operations.



SEIU HQ Occupancy & Consumption (Annually)

Estimated Occupants	Annual Water Consumption (gallons)
100	2007500
150	3011250
200	4015000
250	5018750
300	6022500
350	7026250
400	8030000

WATER EFFICIENCY

AWARDED: 13 / 14

WEp1	Minimum indoor plumbing fixture and fitting efficiency	REQUIRED
WEc1	Water performance measurement	2 / 2
WEc2	Additional indoor plumbing fixture and fitting efficiency	5 / 5
WEc3	Water efficient landscaping	5 / 5
WEc4	Cooling tower water Mgmt	1 / 2

The SEIU Headquarters at 1800 Massachusetts Avenue in Washington, D.C. earned LEED Platinum certification under the LEED v2009 Operations and Maintenance (O+M) rating system. In its 2017 recertification, the building achieved a total of 80 out of 110 points, meeting the minimum threshold for Platinum. The project performed especially well in Water Efficiency, earning 13 out of 14 points through strategies like water performance measurement, indoor plumbing fixture upgrades, and full points in water-efficient landscaping. It also scored highly in Sustainable Sites (22 out of 26), Energy and Atmosphere (25 out of 35), and Innovation (6 out of 6), reflecting strong efforts in commuting strategies, energy commissioning, and operational best practices. These results highlight the building's ongoing commitment to sustainable maintenance and performance, even within the constraints of an existing urban structure.

Other Findings

Through my research, I have identified several inefficiencies in these centralized systems such as excessive waste generation, inconsistent water quality, high energy usage caused by transportation, outdated systems, and distribution strategies. Noticeably, this has lead to an increasing adoption of green building practices and stricter environmental standards to combat some of these issues. This has allowed me to see a unique opportunity to normalize the application of advanced hydrophilic filtration technologies. However, rather than applying them to new commercial buildings I am suggesting that system retrofitting existing urban buildings. In this way, it is achievable to reduce waste, while providing safer, self-sustaining, and long-term water management solutions. Allowing urban cities to become more adaptable over time, reducing the overall strain of increasing populations.

Adaptive Reuse Application

The focus on adaptive reuse is critical to my argument. While decentralized hydrophilic technologies are already recognized as efficient, their application in adaptive reuse projects offers unique advantages, such as reduced environmental impact and enhanced integration into existing urban frameworks. When approaching an adaptive reuse project the American Institution of Architects (AIA) in their Guidebook: Buildings that Last, explains that separating operational systems like water can "[make] systems easier to repair and replace is also a benefit, in the event of damage from the elements. Having a more robust structural system can also provide greater resilience." Applying this to the building plan analysis above, there is a clear pattern of consolidated plumbing fixtures and systems that can be maintained, replaced, or upgraded without later damaging the building or to other services (AIA, 2023). This prevents confusion and also presents opportunities to address water scarcity in a way that balances sustainability and building preservation. Unlike new construction, adaptive reuse allows for the retention of site-specific and historical characteristics while upgrading infrastructure to meet contemporary water efficiency standards. Using alternative building examples like Perry Hall, or Hotel Emma lay a framework of how to maintain the building's integrity while also expressing a clear sustainable agenda.

Building Management System (BMS)

Many LEED-certified buildings, including those examined in this research, rely on Building Management Systems (BMS) not only during design and construction but as long-term tools for optimizing building performance. According to the U.S. Green Building Council, BMS platforms allow facility teams to monitor and control key systems like water, HVAC, and electricity, providing real-time data to support efficient operation (USGBC, 2023). What makes BMS particularly valuable is its ability to track water usage patterns, monitor fixture performance, and detect leaks through sensor integration. This continuous feedback loop helps teams make informed, data-driven decisions to support ongoing water conservation goals. By extending its use beyond occupancy, BMS ensures sustainability strategies remain active, adaptable, and measurable over the life of the building.

Further Discussions & Implications

I aim to discuss the associated implications and obstacles I had to endure throughout the data collection process. First being policies surrounding obtaining access to original building construction and plumbing documents. For example, the state of California prevents the public from accessing these documents through the Senate Bill 1214. This implementation was recent and was established for, "the purpose of… protect[ing] the intellectual property rights of architects as provided by the Federal Copyright Act," (AIA, 2024). This prevented me from gaining access to Case Studies found specifically within California. Another obstacle is my use of purely qualitative literature and Case Study analysis; arguably this is acceptable for the premise of my research as I am taking an architectural design approach. However, in the future the exploration of tangible data through physical testing or simulation software, can be quite beneficial and offer alternative perspectives. This evidence-based approach could ensure the validity of my findings and their technical applicability to commercial building practices. But by focusing on existing datasets and building performance metrics, I optimize my analysis and develop actionable insights for implementing decentralized water systems for future projects.

My research evidence is complemented by insights from discussions with architectural professionals familiar with LEED sustainable design. These professionals provided valuable perspectives on the challenges and opportunities of integrating decentralized systems into adaptive reuse projects. Susan Atkinson, the lead principle of the American Indian Hall LEED Platinum Project. She expressed ways in which she was able to track water efficiency throughout the project and how native ideology can be used as a bridge to mend the gap between industrialization and natural sustainable practice. By utilizing Low Impact Design (LID), roofscapes, building metrics, and if regionally applicable rainwater reclamation through cisterns. I was also given the chance to discuss the Bullitt Center with David Fish, who was also a principle of the project. He shared that currently, "the building [is] off the city's water grid," and that they were not allowed to have a fully decentralized system but, "[he] understood that it was set up such that if in the future they were allowed to do so, that they could effectively 'flip a switch' to shut off the incoming water supply and continue to run as normal." These conversations were beneficial in furthering my research and demonstrated further how municipal policies and architectural practice are interlaced.

In conclusion, my research demonstrates that decentralized water conservation technologies not only address the inefficiencies of centralized systems but also provide a compelling solution for sustainable water management in adaptive reuse projects. These systems enable commercial buildings to improve water efficiency, reduce energy consumption, and minimize waste, contributing to broader environmental and economic goals. By emphasizing the role of adaptive reuse, my findings add a critical dimension to the discourse on sustainable architecture, highlighting the potential of hydrophilic technologies to transform existing infrastructures into models of efficiency and resilience.

Results

Adaptive Reuse Building & Site

The project explores the adaptation of a building water system within an adaptive reuse context, designed for a site along the South Platte River just south of Empower Field at Mile High Stadium in Denver, Colorado. Through precedent analysis and case study comparisons, including both LEED-certified new constructions and adaptive reuse projects, this design identifies opportunities and limitations when implementing decentralized water systems in an existing structure.

The selected site, the 120-year-old Xcel Energy Steam Power Facility, offers both historical significance and strategic positioning within a rapidly redeveloping area of the city. Its proximity to the river and its location near new mixed-use developments position it as an ideal candidate for a sustainable transformation into a community-driven space. The project proposes repurposing the facility into a Hotel Venue, reinforcing the area's emerging identity as a social, economic, and recreational hub.

LEED & Living Buildings Framework

The redevelopment aligns with LEED's Commercial Hospitality framework, guiding the water efficiency strategies used in the design. Drawing from the Living Building Challenge (LBC) principles, the water system also integrates concepts of net-zero water usage and ecological responsibility. Special consideration is given to the South Platte River, which acts as the natural basin for stormwater redistribution on the site. The design takes advantage of the site's hydrological context by intercepting and reusing rainwater and greywater flows that would otherwise burden the river ecosystem.

Unlike new construction projects with more flexibility for full system integration, this adaptive reuse required strategic retrofitting to accommodate the building's existing infrastructure, which placed limits on system size, routing, and capacity. These constraints mirror broader patterns observed in case studies, where adaptive reuse projects, despite limitations, can still achieve meaningful conservation outcomes through creative system design and integration.

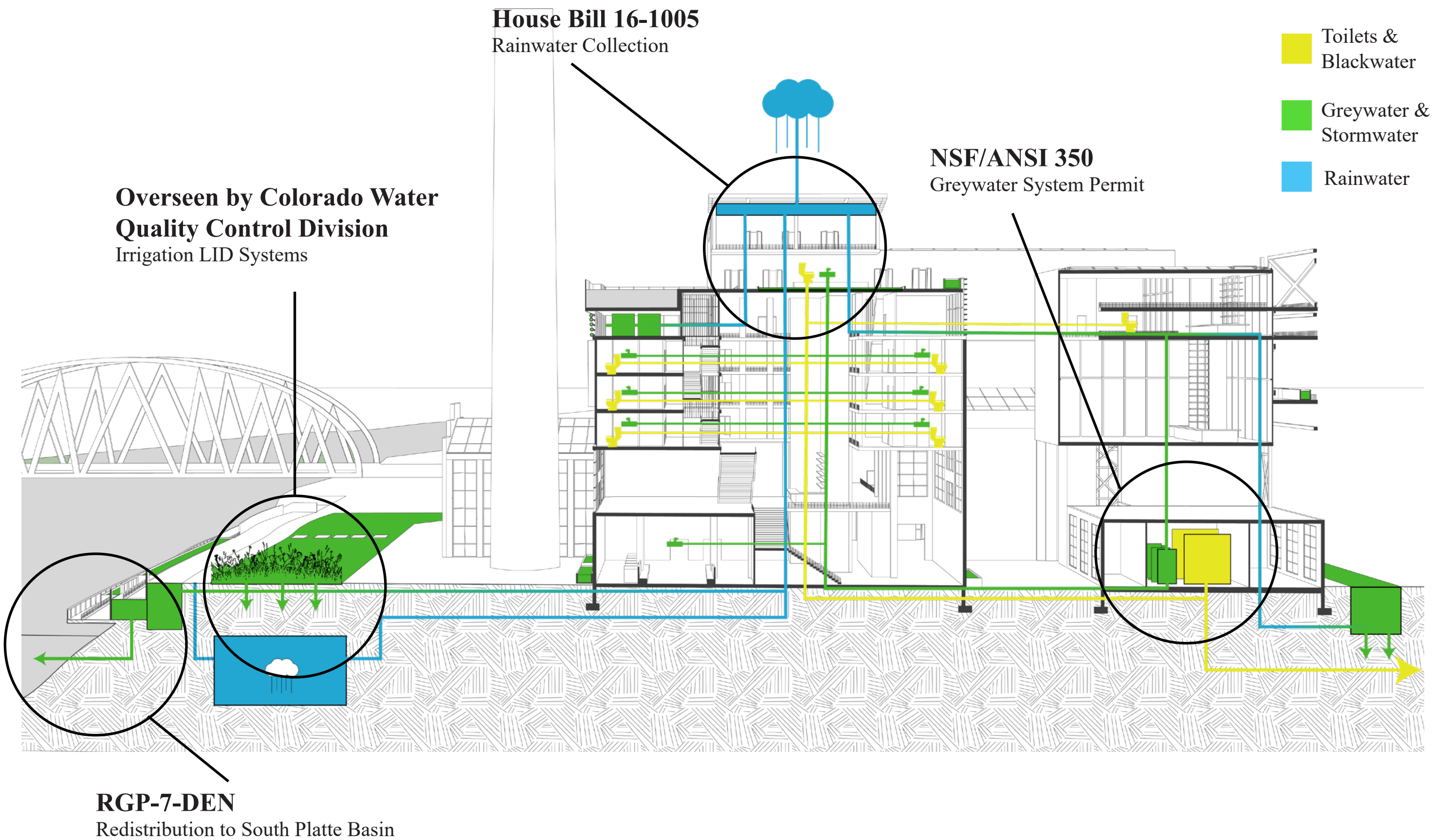
Implemented Systems

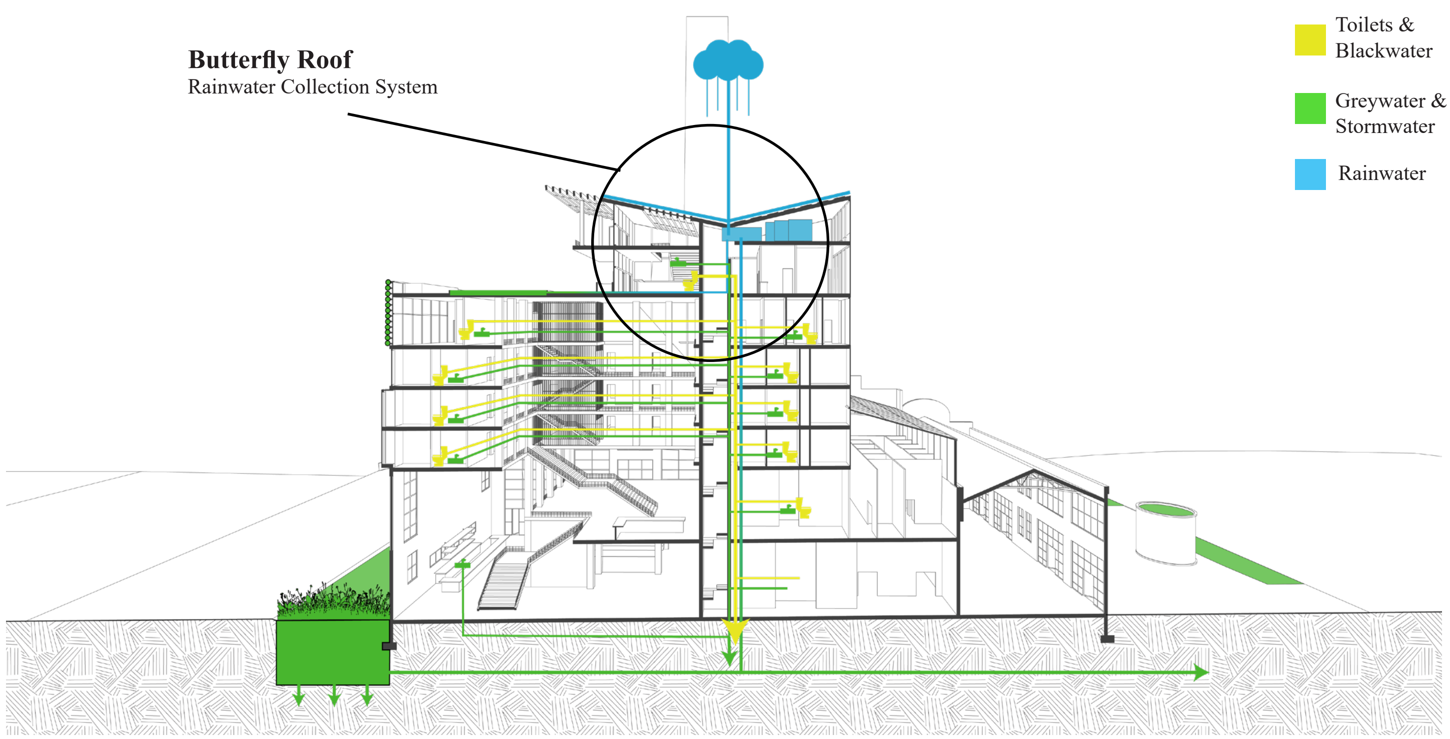
The integrated water system is illustrated through a series of diagrammatic representations (refer to the attached image), emphasizing the flow and treatment sequence within the building.
Based on the analysis of best practices and technical literature, the water filtration strategy consists of two potential system pathways:

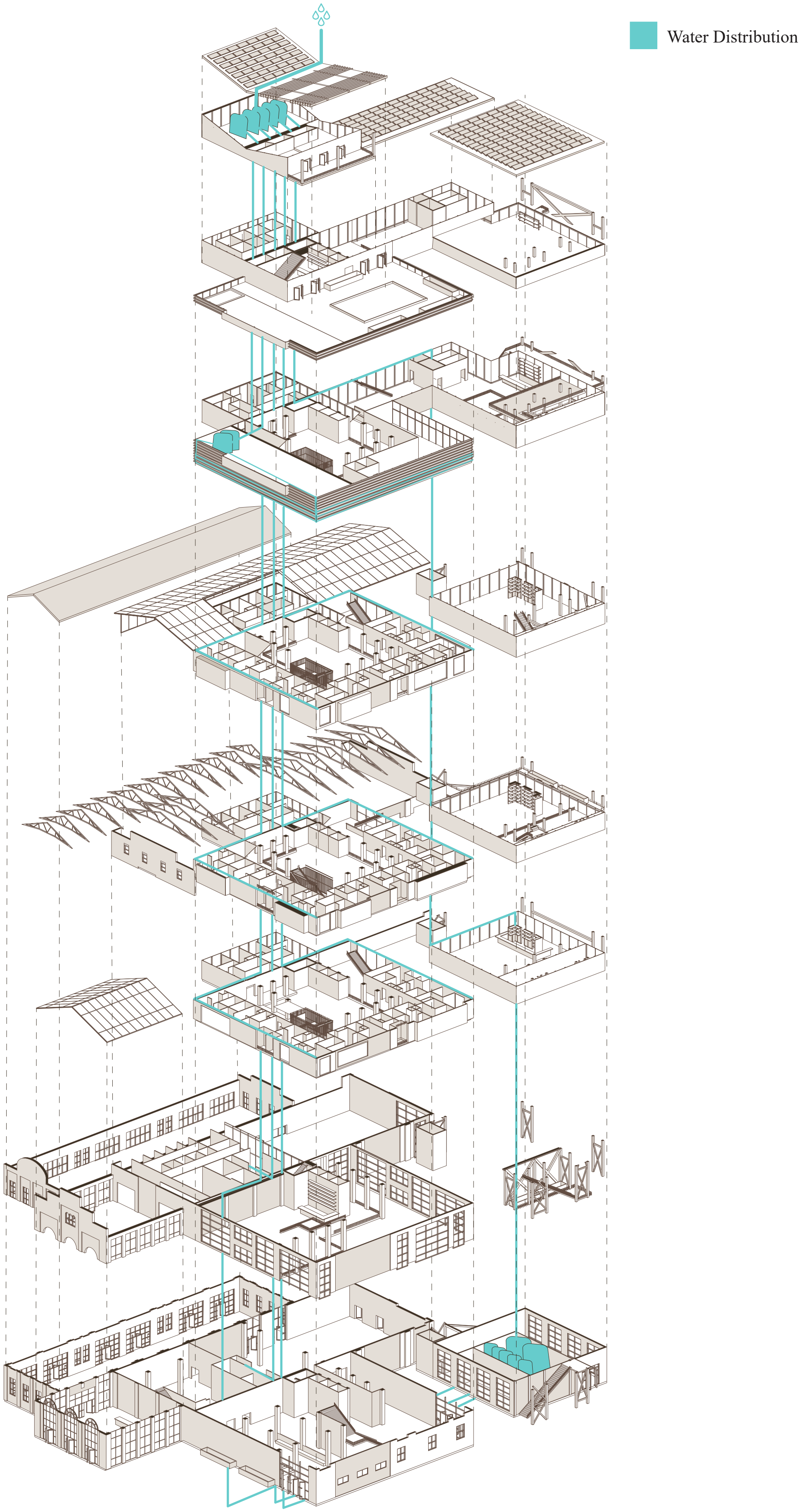
1. Stormwater Management → Greywater Reuse → Ceramic Filtration → UV Sanitation
This path prioritizes the capture of rooftop and surface runoff, directing it through greywater systems where it is filtered via ceramic membranes and disinfected through UV sanitation units. This treated water can be safely reused for non-potable applications such as toilet flushing, irrigation, and cooling systems.

2. Direct Greywater Capture → Ceramic Filtration → UV Sanitation
In this secondary option, greywater generated from showers, sinks, and laundry is directly treated and cycled back into the building's operations with minimal stormwater input, optimizing internal water recycling when external capture is limited.

The use of a butterfly roof in building design is an innovative strategy aimed at enhancing water collection during rainfall. This distinctive roof design features two sloped sections that meet at a central valley, creating a "V" shape. The central depression funnels rainwater into a collection system, allowing for efficient storage and utilization. By directing rainwater towards a central point, the butterfly roof not only maximizes water capture but also minimizes runoff, making it an ideal feature for buildings aiming for water conservation.


House Bill 16-1005
Rainwater Collection
Toilets &
Blackwater
Greywater &
Stormwater
Rainwater
NSF/ANSI 350
Greywater System Permit
Overseen by Colorado Water
Quality Control Division
Irrigation LID Systems
RGP-7-DEN
Redistribution to South Platte Basin


Butterfly Roof
Rainwater Collection System
Toilets &
Blackwater
Greywater &
Stormwater
Rainwater


Water Distribution

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Appendix

RGP-7-DEN:
This is a Regional General Permit issued by the U.S. Army Corps of Engineers (Denver Regulatory Office), not the Colorado DWR, but it operates within Colorado jurisdiction. It authorizes specific activities, such as stream channel stabilization, maintenance, and minor construction work, in waters of the United States, including parts of the South Platte River Basin.

It is especially relevant for local agencies like the Mile High Flood District and others performing regular flood control or infrastructure maintenance. While Colorado DWR handles water rights and distribution, RGP-7-DEN facilitates environmentally responsible development and maintenance in regulated waterways, provided projects meet strict design, mitigation, and notification conditions.

NSF/ANSI 350:
This is a nationally recognized performance standard that sets the treatment requirements for onsite residential and commercial greywater systems, particularly those used for indoor applications such as toilet and urinal flushing or landscape irrigation with potential human contact. In Colorado, and specifically under Denver's greywater regulations guided by Regulation 86, compliance with NSF/ANSI 350 is typically required for indoor reuse systems to ensure the treated greywater meets health and safety standards through biological treatment, filtration, and disinfection. However, this standard is not mandatory for subsurface irrigation systems (Categories A & B), which pose minimal public exposure risk. While full bypassing of NSF/ANSI 350 is rare, there is some flexibility for commercial or pilot projects, especially those demonstrating innovative systems with limited human exposure, third-party validation, and robust monitoring. In these cases, project developers may negotiate alternative compliance paths with local health departments if they can prove equivalent or superior water safety and system performance.

CO Regulation 86:
Colorado Regulation 86 establishes the legal framework for the use of greywater within the state, outlining how greywater can be collected, treated, and reused for non-potable applications such as subsurface irrigation and toilet or urinal flushing. The regulation categorizes systems into four types (A-D), based on use and building type, and defines treatment and monitoring requirements accordingly. While it enables local governments to permit greywater reuse, it is not automatically active statewide, jurisdictions like Denver must formally adopt and implement it. Regulation 86 is particularly significant because it allows local municipalities to tailor greywater policies to their infrastructure and public health needs. In terms of flexibility, while the regulation sets minimum performance standards (including NSF/ANSI 350 for indoor use), local agencies have discretion to approve alternative systems or pilots, especially for outdoor, subsurface uses that pose minimal public contact. Therefore, although Regulation 86 sets the baseline for legal greywater use, its enforcement and adaptability largely depend on local agency interpretation and permitting frameworks.

Permit No. CO0032999:
This is a Colorado Discharge Permit issued under the Colorado Department of Public Health and Environment (CDPHE), not the Colorado Division of Water Resources (DWR). It authorizes the Littleton/Englewood Wastewater Treatment Plant to discharge treated effluent into the South Platte River under the Colorado Discharge Permit System (CDPS). While the DWR manages water rights, usage, and well permitting, this permit specifically regulates water quality, ensuring that it meets standards to protect downstream ecosystems and public health.