EPiC Series in Built Environment
Volume 5, 2024, Pages 566–574
Proceedings of 60th Annual Associated Schools of Construction International Conference

Opportunities for Improving Water Efficiency on LBC Projects in Semi-Arid Climates: Colorado Case

Trevor Wahl, Rodolfo Valdes-Vasquez, Ph. D., and Svetlana Olbina, Ph.D.
Colorado State University
Fort Collins, Colorado

Sustainable design and construction continue to gain traction, and more projects are incorporating water usage and efficiency practices into their designs. These practices are important in sustainable building and are prevalent in many projects. This study aimed to examine the Living Building Challenge (LBC) rating system and identify its standards for water efficiency, which are described by the water petal. The feasibility of incorporating water imperatives described in the water petal was investigated by conducting site visits to three projects in Colorado. Observational goals for each site visit were clearly defined as part of the data collection and helped analyze each project. The challenges and successes of each project are also identified and discussed. The results indicated that Colorado water law is one of the most significant challenges, along with the failure of design teams to coordinate with municipalities or utility companies early in the design process. However, progress has been made throughout the three projects, with reduced water usage and efficiency becoming more prevalent in later projects. Efficient water usage will continue to gain importance as the scarcity of water increases; therefore, it is essential to continue working towards incorporating responsible water practices in future projects.

Key Words: Sustainable Building, Living Building Challenge, Water Efficiency, Water Petal, Water Imperatives, Responsible Water Use, Net-Positive Water

Introduction

As the availability of natural resources continues to decrease, there has been an increased push to improve efficiency and conserve resources in the many facets of everyday life. Construction is no exception and has recently seen considerable effort to improve efficiency and resource consumption. In the United States, buildings are responsible for 41 percent of primary energy usage and 39 percent of annual CO_2 emissions (EESI, 2023). Typically, construction processes and materials have remained relatively unchanged compared with other industries, and this has given the construction industry a reputation for being wasteful and harmful to the environment. However, with the introduction of the concept of sustainable design and construction, the architecture, engineering, and construction (AEC) industry has taken positive steps towards reducing the environmental impact of buildings.

This study aimed to examine the Living Building Challenge (LBC) projects in Colorado and analyze each project's water aspects as described by the water petal. Since the study focuses on projects located in Colorado, it is essential to discuss the water laws and rights enforced throughout the state.

The majority of Colorado can be described as a semi-arid climate, and the state has much stricter water regulations than other parts of the United States. Denver Water describes the legal landscape of the water-scarce region through prior appropriation, water rights, beneficial use, call, and return flows. Essentially, water rights do not depend on land ownership, but instead are determined based on when water rights were acquired. Water rights refer to "*A property right to make beneficial use of a particular amount of water with a specified priority date*" (Denver Water, 2023). Dating back to early expansion in the Western United States, individuals who were first to file for water rights were awarded senior rights. Many individuals awarded senior water rights were downstream of Colorado. A resulting 10,434,000 acre-feet of water leaves Colorado annually (Denver Water, 2023). Water rights also apply to rainwater collection; homeowners can only store 110 gallons or less. Rainwater harvesting is considered a collection of runoffs from rooftops, concrete patios, driveways, or other impervious surfaces (Cabot et al., 2016). Rainwater collection is not permitted in most situations without specific approval or permits. House Bill 09-1129 outlines that developers may collect rainwater only with the state engineer's and the water court's approval (Cabot et al., 2016).

Colorado has also imposed strict regulations on graywater use. Using graywater is essential in working towards standards set by the LBC water petal. Graywater includes water discharges from fixtures such as showers, washers, and sinks. Current Colorado law governs that graywater can only be captured and reused in areas where local governments have adopted an ordinance in which the use of graywater is approved (Denver Water, 2023). While the city of Denver has approved graywater reuse, many other counties or cities in Colorado have not. This may pose a significant barrier to projects aiming to achieve the water imperatives set by the LBC certification.

The LBC water petal aims to alter how people value water as a precious resource. The petal also focuses on the chemicals and energy used when treating or transporting water and the reuse of wastewater. Ideally, the water petal will assist in creating an environment in which projects can harvest water to sustain a population sufficiently while also respecting the needs of the surrounding ecosystems. The water petal consists of two imperatives: Responsible Water Use and Net Positive Water. The Responsible Water Use imperative requires using non-potable water for irrigation and less water for other project needs than a baseline regional building of the same type. New buildings must use less than 50 percent of the baseline, and existing buildings must use less than 30 percent (International Living Future Institute, 2019). The Net Positive Water Imperative requires 100 percent of the project's water requirements to be met through captured precipitation or another closed-loop system. Additionally, all projects must manage gray and black water through on-site treatment processes.

Based on the requirements set forth by the LBC water petal imperatives, this study aims to examine the feasibility of each imperative in the Colorado climate setting. This was achieved by reviewing public records, observing current LBC projects in Colorado, and analyzing past research on sustainable water usage systems.

Literature Review

The focus on sustainable design and construction has increased as more projects have adopted green practices, such as water efficiency. Sustainable buildings aim to be environmentally responsible and resource-efficient through all stages of a building's life cycle, including design, construction, operation, maintenance, and demolition (Attia, 2016). The Leadership in Energy and Environmental Design (LEED) system was created by the US Green Building Council in 1993. This rating system is one of the more well-known systems attributed to sustainable building. Additional rating systems include EnergyStar, the WELL Building Standard, and the Green Globes system (Knox, 2021). Each sustainable building system can have separate criteria or focuses, but they all share a similar goal to reduce the negative impacts of the built environment.

While reducing impact is a reasonable goal, another emerging rating system has aimed to take it a further step forward. The Living Building Challenge (LBC) was created in 2006 by the Cascadia Green Building Council. The LBC aims to reduce the built environment's impact and provide a regenerative impact to the built environment. This goal is achieved through requirements that are divided into groups called petals. There are seven petals: Place, Health and Happiness, Equity, Beauty, Water, Energy, and Materials. Each of these petals has imperatives, adding up to 20 in total. Each specific imperative must be met to achieve a Living Building Certification. Currently, 34 fully certified projects and 178 partially certified projects are in the United States. In the state of Colorado, there is presently only one certified living building project and two partially certified projects (ILFI, 2023).

Previous research has focused more on the theory behind sustainable building, its expectations, and its feasibility. The idea of net zero is still relatively new and improves upon current sustainability standards. Murphy (2016) compared projects that have achieved net zero to standards set forth by the LEED rating system. Specifically, many LEED projects fall short of water treatment and efficiency compared to net-zero projects (Murphy, 2016). Research has also compared net zero to net positive and how each should be defined. Cole (2013) describes net positive as adding value by generating more than a building may need to fulfill its needs. Net zero is defined as only consuming resources that a building can produce renewably (Cole, 2013). Net-positive standards aim to leave the ecology better than before a building's development as opposed to "doing less harm," as net-zero projects aim to achieve.

There appears to be a gap between low-energy and water-efficiency buildings in arid climates, as more literature focuses on energy efficiency. Along with general sustainable design and construction theory and feasibility, it is also essential to investigate specific research relating to each LBC water petal imperative. Studies on net zero or net positive projects do not always specifically include water usage; if they do, they are typically in non-semi-arid climates. For instance, the case studies covered below in Pennsylvania or Massachusetts are in areas where there may be a surplus of water or where water shortages may not be common.

Life cycle assessments can be an effective way to gauge water efficiency and usage for a singular project. A 100-year life cycle assessment on the Frick Environmental Center in Pennsylvania details the systems used to achieve net-positive water, including geothermal wells, rainwater collection systems, permeable pavement, and onsite water purification (Gardner et al., 2020). The assessment confirmed that net-positive water was achieved, but the lack of a closed loop system and aeration in the septic system contributed heavily to the building's global warming potential. This analysis can help future projects also looking to achieve net-positive water usage.

Shillington et al. (2019) went a step further and specifically evaluated the performance of the water treatment system for the Living Building located in Massachusetts. The Kern Center for Hampshire's College utilizes waterless composting toilets to avoid blackwater in the building. All other water is classified as graywater and is entered into the system through one of two fixtures. Once the water is present in the system, it is sent through primary or secondary treatment (Shillington et al., 2019). The study successfully confirmed that the system effectively removed contaminants from the graywater samples examined. The Living Future Institute (2016) also conducted a case study outlining the Bullitt Center in Seattle, Washington. The project utilizes rainwater harvesting, graywater reuse, and blackwater treatment to achieve net positive and responsible water usage standards. The building has an elevated wetland present on the third floor for graywater reuse. Permits and local regulations were identified as significant challenges in the case study. These challenges were overcome through consultation with local authorities and certifying the project as a public water system. This allowed the system to be approved under established local guidelines.

The lack of LBC-certified projects has challenged the amount of research that can be performed on decentralized graywater systems and their feasibility in Colorado. However, previous studies have analyzed the challenges faced by other buildings in implementing decentralized graywater treatment systems. Spahr (2012) examined the environmental, economic, and water-saving impacts of a LEED-certified building in Boulder, Colorado. Williams Village North at the University of Colorado Boulder collects graywater from sinks and showers in the building to be treated on-site and recirculated through the building to assist with the demand from flushed toilets. The treatment system for the residence hall was found to effectively reduce water usage for the building and meet goals for water sustainability. The study determined that the economic and technological inefficiencies as well as constraints implemented by Colorado water rights, produced challenges for the system (Spahr, 2012).

Research Methodology

Existing literature was used to establish definitions, previous studies, and water efficiency innovations that have been explored for other projects. A lack of information was found for implementing the LBC water imperatives in Colorado. While a large number of LEED-certified projects in Colorado are available for research, a few key factors provided motivation to focus solely on LBC Projects in this study. LEED certifications can be achieved by obtaining a specific number of points, a higher total number of points achieved equates to a higher project rating. Out of the 110 points available for projects, only 11 focus on water efficiency, while 46 focus on energy and materials (Knox, 2021). A project can technically achieve a LEED certification without addressing any water-focused aspects. Consequently, LEED and LBC projects are not easily comparable, as LBC projects must address imperatives described in the water petal. Thus, exploratory research was implemented by focusing on publicly available records and LBC project observations (i.e., site visits) to examine progress regarding net-positive water usage and overall water efficiency.

Projects were selected from the Living Future Projects Map provided by the Living Future Institute (2023). Each project is classified differently or pursuing a different classification. The three projects selected were the only ones listed on the Living Future Projects Map in the state of Colorado. Specific details and certifications for each project are provided in Table 1. Each project site visit aimed to achieve the same research goal: observing the design scope taken towards water efficiency, the degree of water efficiency achieved, and any barriers to reaching the water imperatives for each project. Essential observational goals about the water aspects of each project are listed in Table 2.

Table 1

Colorado LBC projects

Project	Certification	Status	Occupancy Date	Project Area
Rocky Mountain Innovation Center	Petal Certification	Certified	2017	15,610 SF
Pikes Peak Summit Complex	Living Building	In Progress	2019	37,255 SF
Northglenn City Hall	Core Energy	In Progress	2024	36,094 SF

Table 2

Established goals for observations made at LBC projects

Goals	Description
Goal 1	Identify how the project practices responsible water usage.
Goal 2	Identify aspects of the project that allow for improved water efficiency.
Goal 3	Recognize which design aspects were considered for the project to reach the imperatives described for the Water Petal of the LBC.
Goal 4	Examine any land use or building regulations that challenge net-zero or net-positive water usage.
Goal 5	Examine any other challenges to reaching the imperatives described for the Water Petal.
Goal 6	Identify recommendations for future projects that can be employed to improve water usage and efficiency.

The observational studies revolved around coordinating a site tour with a project's contractor, facilities manager, etc. Once a site tour was scheduled, the observational goals listed in Table 2 were sent to all parties involved with the tour. Observations conducted during the physical tour included: visuals of the project, asking questions about the project, reviewing documents or construction drawings, and discussing future recommendations. Each project visited shared related questions that were kept as consistent as possible. However, as only one author was involved with the project observations, possible biases could exist. Biases from background research conducted before the site tours or from the results of previous site tours may have been prevalent.

Results

This section presents the results of the observations made at each project site. Table 3 demonstrates how the six observational goals were met for each project.

Table 3

Observational results for project site tours

Goals	Rocky Mountain Innovation Center	Pikes Peak Summit Complex	Northglenn City Hall
Goal 1	Non-potable irrigation is supplied through downspout collection.	Rainwater collection systems and water treatment systems.	Non-potable irrigation is supplied through rainwater collection.
Goal 2	No systems contribute to improved water efficiency.	Vacuum toilet and low-flush fixture systems. 75% water reduction.	No systems contribute to improved water efficiency.
Goal 3	Building footprint and irrigation system.	Graywater treatment and plumbing systems.	Filterra structures and irrigation system.
Goal 4	Absence of water rights and building footprint location.	Absence of water rights to utilize rainwater collection system.	The larger size of the project did not allow for a closed-loop system.
Goal 5	Lack of design initiative and intention.	No other notable challenges.	Lack of design initiative and intention.
Goal 6	Increased collaboration with local municipalities.	Reduced restrictions for commercial projects.	Design initiatives for efficient water fixtures.

Project 1: Rocky Mountain Innovation Center in Basalt, Colorado

The Rocky Mountain Innovation Center is a commercial office space that has achieved the Petal Certification under the LBC. The Rocky Mountain Institute is a nonprofit organization accelerating the transition to clean energy and a zero-carbon future. The Innovation Center embodies the Site Petal, Energy Petal, Equity Petal, and Beauty Petal. The focus for the building was placed on the Energy Petal and creating a net-zero energy building. The project reached the net-zero energy imperative by utilizing passive heating and cooling from the mountain climate, automated blinds and windows, and a photovoltaic system on the roof. The Innovation Center did not achieve a petal certification for the water imperatives set by the LBC.

The building operations manager led the project site visit and allowed for insights into the challenges and successes regarding responsible water use and efficiency. The Innovation Center takes rainwater runoff in a downspout system located on the south side of the building. This system supplies the irrigation for the building as a non-potable water source. The project also enhances the surrounding wetlands and collects water from the site to filter and direct towards the river flowing by the building. This project met many of the goals described in the Responsible Water Use Imperative but could not achieve the Net Positive Water Imperative. Challenges observed for meeting the water petal imperatives included: a lack of design for an onsite wastewater treatment system, the limitations to the building footprint from the Roaring Fork River located on the south side of the building, and the absence of water rights in the town of Basalt. Without access to water rights, the building cannot utilize a majority of snow/rainwater runoff and create a closed loop system. A closed-loop system and on-site water treatment plant are also very design intensive, making it difficult to integrate them within the project’s limited footprint. Future recommendations from this project include increased design focus on water efficiency and increased collaboration with the local municipality on water rights for the project.

Project 2: Pikes Peak Summit Complex in Cascade, Colorado

The Pikes Peak Summit Complex is a commercial visitor center that is currently pursuing a Living Building Challenge certification. This would make the project one of a select few projects to be fully LBC-certified in Colorado. The Summit Complex aims to minimize its impacts on the mountain’s ecosystem and be as self-sufficient as possible. As it is pursuing an LBC certification, the project has aspects meant to meet all seven petals and the imperatives set forth by each petal. For instance, the project also has an offsite solar array to supply most of the building’s energy (RTA Architects, 2021). The Summit Complex has designs in place to meet the water petal imperatives but has not achieved the certification.

The project site was not visited in person; however, observations were made through the Road to Sustainability video series and other research conducted on the project (RTA Architects, 2021). A vacuum toilet system and low-flush fixtures were installed in the building to reduce water usage. This system can help reduce water usage by up to 75 percent. The project also has an onsite treatment plant located in the basement that treats graywater from sinks and other fixtures and reuses that water to flush the toilets. The Summit Complex is one of the few projects in Colorado that have been approved to reuse water that has been treated on-site. Approval for wastewater reuse involves input from Colorado water authorities and the health department. The project has also implemented a rainwater collection system that can be employed to help the project reach net-zero water usage. However, current Colorado water laws do not allow for the rainwater collection system to be used in commercial buildings. The design team took substantial considerations to reach the Water Petal Imperatives, but the extreme climate and water rights laws have proved to be barriers to full completion of the Water Petal Imperatives. Future recommendations for similar projects could encompass compromising with municipalities to lessen restrictions for commercial projects, specifically on rainwater collection.

Project 3: Northglenn City Hall in Northglenn, Colorado

The Northglenn City Hall project is currently under construction and, upon completion, will pursue a LBC Core Green Building Certification. This would make it the first municipal building in Colorado to achieve the certification. The new building will replace the old City Hall and create better infrastructure and ample employee space. Through a Core Certification, the project will have net-zero energy usage, creating all its own energy. The project aims to achieve net-zero energy through automatic controls, sensors, and energy-efficient systems. The Northglenn City Hall does not reach the standards to embody the Water Petal set forth by the LBC.

The contractor led the project site visit and helped provide observations on the successes and challenges regarding responsible water use and efficiency. The building has implemented three underground storage tanks to collect rainwater for non-potable landscape irrigation. The tanks are in the northeast quadrant of the building and can store up to a combined 25,000 gallons. The project also has incorporated two Filterra structures at inlets to filter any storm water before it enters the storm system or is used for irrigation purposes. The Filterra structures are made from precast concrete boxes and include a 3-inch mulch layer, a 6-inch underdrain layer, a 21-inch Filterra media layer, and a planted tree covering the top of the precast box. The efforts to incorporate water filtration and use non-potable irrigation meet many of the standards set by the Responsible Water Use Imperative. However, no net-positive or net-zero water efficiency measures will be met by the project. As a municipal project, the design team worked with the City of Northglenn to obtain some water rights for the project, allowing the storage of rainwater onsite. While this is a step in the right direction, the Northglenn City Hall did not implement a closed-loop water system and may not have had sufficient resources or space to incorporate a wastewater treatment plant. Future recommendations should include a continued improvement of design initiatives to incorporate more efficient water fixtures. However, it is encouraging to observe increased cooperation between project design and municipalities regarding water rights and the ability to store rainwater.

Discussion

The lack of LBC-certified and Living, Petal, or Core buildings in Colorado made it difficult to fully identify the successes and challenges of projects in terms of water usage and efficiency. However, each of the three projects observed did show indications of challenges meeting both water imperatives described in the water petal. A common challenge for each project was identified to be the Colorado water regulations and water rights in place throughout the state. However, progress was observed in terms of working with Colorado water regulations. The Rocky Mountain Future Institute, completed in 2017, could not treat any water on site or store runoff from the project site. The Pikes Peak Summit Complex completed in 2019 obtained approval and incorporated an on-site graywater treatment plant. The project also incorporated a rainwater collection system, but the system cannot be currently utilized because of Colorado water regulations. The new Northglenn City Hall (currently under construction) worked with the City of Northglenn to obtain approval to store runoff water on-site for the project irrigation system. The project teams seem to have been attempting to work with municipalities to incorporate water storage and improve water efficiency.

There appears to be a reluctance in the design phase to work with local municipalities to integrate or explore possibilities for responsible water usage. Many design teams may be able to achieve this by working with local utility companies to create detailed augmentation plans early in the project design process. It is important to note that some municipalities may simply have little control over the water rights, making early design communications much less impactful. Additionally, legal battles over water rights with municipalities or utility companies are possible, which can make it difficult to justify allocating extra time and money. These challenges can be lessened through a larger push to alter the existing legislation or to encourage cooperation between utility companies, municipalities, and designers. The Northglenn City Hall project showcased this through cooperation with the City of Northglenn, allowing the project to store excess rainwater on site. Increased communication between all involved parties regarding water usage and efficiency should be encouraged. Projects can also aim to, at the very least, incorporate rainwater collection systems that can be utilized in the future if legislation is altered. The Pikes Peak Summit Complex included rainwater collection features so that the project may achieve net-zero water usage in the future. Significant changes would have to be made to water laws that govern the Western United States to allow for runoff water collection. As this could prove difficult, smaller compromises could be made to allow for water treatment and collection exceptions. Increased cooperation could incorporate more responsible water practices into future projects.

Conclusion

The study aimed to investigate LBC projects in Colorado and their ability to reach the water imperatives established by the LBC water petal. This included achieving responsible water usage and net-zero or net-positive water usage. It was determined that while projects have taken promising steps towards improving water efficiency and water usage, the projects observed were unable to meet the goals of the Water Petal. Numerous challenges are in place for each project, including water regulations, design initiatives, and overall water availability. It should be noted that net-zero and net-positive water usage is achievable in the Colorado climate. Other barriers were discovered to pose more difficulty than simply the amount of water a project site is exposed to throughout the year.

It was assumed that the water fluctuation in Colorado would pose the main challenge for projects pursuing Living Building Certifications. The Colorado landscape can often experience droughts or periods with less exposure to water. It was unexpected to conclude that from the projects observed, human-controlled challenges would be more prevalent than natural challenges. Additionally, considering the number of fully certified projects nationwide, the lack of registered LBC projects in Colorado and the western United States was unexpected. This may explain the difference in water regulations impacting construction projects across different regions of the country. Case studies for other LBC projects could be examined to identify additional common challenges.

While the information found in the observations of the three LBC projects across Colorado can be useful in creating a general description of water usage and efficiency, the research does not encompass all project certifications, such as LEED projects. The small number of cases in this study was a limiting factor in determining a consistent understanding of sustainable water challenges across Colorado. A larger number of cases would allow for more generalized and complete findings, including LBC projects from surrounding states such as Utah, Arizona, etc. would assist in addressing this limitation. Further research could be conducted on non-commercial projects and projects not pursuing LBC certifications. Research can be performed to include other certification systems, as many also include requirements for water usage and efficiency. Specifically, other projects have incorporated on-site graywater or water treatment plants, which is essential to achieving net-zero or net-positive water efficiency. Steps taken by these projects to overcome legal hurdles imposed by Colorado water law should be investigated. Sustainable building standards will continue to become more common in construction projects and will be obvious in projects without the same rigorous standards as the LBC certification.

References

Attia, S. (2016). Towards regenerative and positive impact architecture: A comparison. *Sustainable Cities and Society*, 396-406.

Cabot P.E., Olson, C.C., Waskom R.M., & Rein K.G. (2016). Rainwater Collection in Colorado. *Colorado State University Natural Resource Series*, 1-4.

City of Northglenn (2023). New City Hall. Retrieved from City of Northglenn: https://www.northglenn.org/government/project_updates/new_city_hall.php

Shillington, C.N., Cianfrani. C.M., Hews, S. (2019). Evaluating the performance of a decentralized graywater treatment system in a living building at Hampshire College, Amherst, MA, USA. *Water Environ Research*, 2(2), 291-301. doi: 10.1002/wer.1251.

Cole, R. J. (2013). Shifting Performance Expectations: Net Positive Buildings. *Central Europe Towards Sustainable Building*, 1-6.

Denver Water. (2023). Water Law. Retrieved from Denver Water: https://www.denverwater.org/about-us/how-we-operate/water-law

Environmental and Energy Study Institute (2023). Buildings and Built Infrastructure. Retrieved from Environmental and Energy Study Institute: https://www.eesi.org/topics/built-infrastructure/description

Gardner, H. M., Hasik, V., Banawi, A., Olinzock, M., & Bilec, M. M. (2020). Whole Building Life Cycle Assessment of a Living Building. *Journal of Architectural Engineering,* 26(4), 04020039.

Hunt, W. (2008). Literature Review of Data on the Incremental Costs to Design and Build Low-Energy Buildings. *Pacific Northwest National Laboratory*, 1-38.

International Living Future Institute (2019). Living Building Challenge 4.0. 1-78.

International Living Future Institute (2023). Our Living Future Projects Map. Retrieved from International Living Future Institute: https://living-future.org/our-living-future-map/

Kats, G. H. (2003). Green Building Costs and Financial Benefits. *USA for Massachusetts Technology Collaborative*, 1-10.

Knox, N. (2021). The role of LEED in climate change mitigation. Retrieved from U.S. Green Building Council: https://www.usgbc.org/articles/role-leed-climate-change-mitigation

Murphy, K. M. (2016). Sustainable and energy-efficient development interventions and their application toward net-zero or net-positive energy and water building development. *Massachusetts Institute of Technology*.

Rocky Mountain Institute (RMI) (2023). The RMI Innovation Center. Retrieved from RMI: https://rmi.org/our-work/buildings/scaling-zero-net-carbon/rmi-innovation-center/

RTA Architects. (2021). Most Recent News at RTA. Retrieved from Pikes Peak Summit Visitor Center Living Building Challenge Video Series: https://rtaarchitects.com/news/pikes-peak-summit-visitor-center-living-building-challenge-visitor-series

Spahr, K. M. (2012). The challenges to implementing decentralized water reuse: A greywater recirculation case study in Boulder, Colorado. Available from *ProQuest Dissertations & Theses Global.* (1112064611).