

# ON-SITE WATER SYSTEMS: FINANCIAL CASE STUDIES

FIRST COST, MAINTENANCE COST, AND RETURN ON INVESTMENT



## 6 PROJECTS

### SIZE RANGE

2,150 - 500,000 SF

### TYOLOGIES

EDUCATION  
MULTI-FAMILY  
SINGLE FAMILY  
COMMERCIAL

### CLIMATE ZONES

SEMI-ARID  
HUMID SUBTROPICAL  
MEDITERRANEAN  
HIGH DESERT  
COLD NORTH

### TRANSECTS

L1, L3, L5, L6

### DESIGNS INCLUDE

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater reuse
- Composting toilet(s)
- On-site domestic sewage treatment
- On-site greywater treatment

In January 2018, the International Living Future Institute (the Institute) and Recode published “Opportunities for Achieving Next Generation Water Infrastructure in CA, OR, and WA.” This report was the result of fifty interviews with innovative

water experts and regulators around the country; it synthesized their experiences into ten of the largest barriers to on-site water capture, treatment, and reuse systems along with suggested solutions.

The third most challenging barrier was titled “True Cost of Water.” According to the experts interviewed, the many unknowns around design and construction costs, operations and maintenance costs, available incentives, and return on investment were a deterrent to the proliferation of these systems. To remedy this situation (and in alignment with the Institute’s core belief in transparency), the Institute collected financial information about the upfront and ongoing costs of implementing on-site rainwater harvesting and/or greywater and domestic sewage treatment and reuse systems.

The following six case studies are selected from the 23 projects around the world that have achieved the Water Petal and others that have integrated innovative water systems. Of the projects surveyed, six were able to provide the level of detailed financial data required to complete a case study.

**“When the well is dry, we know the worth of water.”**

- Benjamin Franklin

# FINANCIAL DETAILS

## RETURN ON INVESTMENT: THE MISSING NUMBERS

Due largely to the value-driven nature of these projects, the Institute was mostly unable to secure or deduce return on investment (ROI) data. Project teams that pursue the Living Building Challenge predominately do so because of a commitment to regenerative design and environmental benefit. Because of this commitment, many of them never created a “business as usual” cost estimate from which a return on investment could be calculated. In other words, a comparison of capital expenditures and operating costs is not available because this data was not used to inform a decision on these projects. Thus, the return on investment data in most of the following case studies is noted as “unknown” - this does not mean that an ROI doesn't exist, just that it has not been calculated.

Additionally, return on investment (as currently calculated) only takes a limited type of quantifiable financial return into consideration, and does little to capture the wide array of social and environmental benefits that these systems provide. These outcomes, known as “stacked benefits” can include the following:

- Increased access to potable water
- Healthier ecosystems
- Lower urban heat island effect
- New high paying green jobs
- Community ownership of water
- Education
- Human connection to water (biophilia)
- Beauty
- Improved water quality
- Less combined sewer overflows
- Reduced pressure on overburdened municipal infrastructure
- Reduced energy use
- Reduced chemical and resource use
- Increased resiliency in case of natural disaster

In light of the barriers encountered trying to calculate return on investment, each case study has a “Key Driver” listed, acknowledging the role that factors other than money played in the decision-making process.

## KEY FINDINGS

Despite the fact that return on investment was difficult to identify in most case studies, there are still ample important takeaways that were discovered.

- **Municipal connection fees make a big difference.** In many jurisdictions, the cost of municipal drinking water and sewer is so minimal that there is little financial incentive for buildings to internalize the cost of on-site treatment. However, most utilities charge connection or capacity fees, which help them maintain the centralized infrastructure, and these fees can be quite significant. Most jurisdictions require Owners to pay this fee whether or not the project relies on the municipal system. In some cases, an exemption from this connection fee can completely cover the first cost of the on-site water system, creating an immediate return on investment—see the Brock Environmental Center case study.
- **Incentives largely don't exist.** Only one project in this study (Battery Park City in New York City) was able to confirm the presence of a local incentive for on-site water reuse systems. Incentives or mandates ([like those in place in San Francisco, for example](#)) are crucial to translate stacked environmental and social benefits into financial benefits for the project team, especially when it comes to first cost.
- **Urban projects tend to be more expensive.** Rural projects tend to have more space to employ natural treatment techniques, which generally translates to a lower first cost. Additionally, rural communities have long relied on well water and septic systems, so the concept of self-sufficient buildings tends to be more readily acceptable. This reduces the soft costs associated with permitting.



## KEY FINDINGS CONTINUED

- **Operations and maintenance needs vary, and offer opportunities for new green jobs.** None of the project teams surveyed were able to quantify the exact cost of labor associated with maintaining their on-site water systems, but each made a point to call out the benefits that come with this work. Maintaining the systems brings the occupants closer to their water cycle, creates countless opportunities for learning, and generates high-paying green jobs in the community.
- **Ongoing annual maintenance costs are minimal.** In general, the costs associated with replacing parts and testing water quality is minimal (under \$1,000 per year for most projects). Testing costs vary greatly across different systems as well as different jurisdictions depending on health requirements. Adopting a national risk-based framework for water quality<sup>1</sup> would greatly benefit the project teams that are required to perform costly tests more often than is necessary to preserve human health.
- **Soft costs are high—for now.** Though most of these projects did not incur or track soft costs (some had this labor donated, others designed the system themselves), it is worth

noting that each of these project teams devoted a significant amount of time and effort to permitting the on-site systems. As with any new or innovative technology, the first to break the barrier will incur the most difficulties as they pave the way for others.

- **There are more benefits to be harvested.** Of the six projects profiled in the following case studies, only three are permitted to spread their composted biosolids on site. The rest (other than Battery Park City, which does not compost on site) send their treated biosolids off site for processing. There is a missed financial opportunity (financial, environmental, and educational) to capture the benefits of nutrient-rich compost for on-site landscapes, replacing the need for fertilizer or other compost. Additionally, most greywater and domestic sewage (i.e. blackwater) enters the treatment system at an elevated temperature (from hot showers, hot sink water, etc.). The technology now exists to capture this heat and use it to offset energy use in the building providing further financial and environmental benefits—see the Battery Park City case study. Both heat energy and valuable nutrients are being underutilized in these systems due to regulatory barriers and lack of knowledge.

## SUMMARY CASE STUDY + COST DATA

Project Name	Building Type	Transect	Project Area (sf)
Tyson Living Learning Center (LLC)	Education	L1	2,968
Eco-Sense Residence (Eco-Sense)	Single Family Home	L3	2,150
Desert Rain	Multi-family Residential	L3	4,810
Brock Environmental Center (Brock)	Commercial	L1	10,518
Battery Park City	Multi-family Residential	L6	375,000
Arch Nexus Office (Arch Nexus)	Commercial	L5	8,252

Project Name	First Costs (USD)			Annual Maintenance Costs (USD)		
	Rainwater	Greywater	Domestic Sewage	Rainwater	Greywater	Domestic Sewage
Tyson LLC	\$75,000	\$50,000	\$115,000	\$665	0	0
Eco-Sense	\$16,000	\$8,926	\$3,340	\$350	0	\$200
Desert Rain	\$35,539	\$26,052	\$71,078	\$370	\$260	\$400
Brock	\$81,000	\$25,000	\$64,000	\$11,000	0	\$1,800
Battery Park City	N/A	\$1,200,000		N/A	\$80,000	
Arch Nexus	\$110,000	\$50,000	\$150,000	0	\$2,272	\$33

<sup>1</sup> <https://sfwater.org/Modules/ShowDocument.aspx?documentID=10493>



# TYSON LIVING LEARNING CENTER

EUREKA, MO | USA

## SIZE

2,968 SF

## TYOLOGY

EDUCATIONAL

## CLIMATE ZONE

SEMI-ARID

## TRANSECT

L1

## DESIGN INCLUDES

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater reuse
- Composting toilet(s)
- On-site blackwater treatment
- On-site greywater treatment

## TOTAL COSTS

HARD: \$240,000


SOFT: UNKNOWN

## ROI

UNKNOWN

## KEY DRIVER

MISSION ALIGNMENT



The Living Learning Center (LLC) is a 3,000 square foot classroom and office facility for Washington University's Tyson Research Center, a 2,000-acre environmental field station in St. Louis County near Eureka, MO. The Center promotes collaborative and interdisciplinary scientific research, facilitates education through apprenticeship, and fosters a diverse community of students and faculty from Washington University and beyond. The Living Learning Center houses a large multi-purpose classroom, a computer lab, office space, and a large outdoor deck creating an indoor/outdoor classroom space. In 2008, the LLC tied for the first building in the world to be certified as a Living Building through the International Living Future Institute.

**“If we’re going to create a research center that is internationally recognized for its work in environmental sustainability, we should also create facilities in harmony with our mission.”**

Jonathon M. Chase, PhD  
Director of the Tyson LLC

# FINANCIAL DETAILS

## RAINWATER TO POTABLE

A sloped metal roof with metal guttering collects precipitation after a first flow diverter protects the rainwater tank from dirt and debris. Rainwater is stored in a 3,000-gallon underground fiberglass collection tank with a shallow well pressurization pump and bladder to maintain water pressure. The water is filtered via two sediment filters, an active carbon block, an ultraviolet sterilizer and sinks with final bacteria barriers at the tap. It is used for all interior uses, including non-potable.

### *Hard Costs:*

#### **TOTAL: \$75,000**

- Potable system: \$60,000
- Non-potable system: \$15,000

### *Annual cost to maintain:*

#### **TOTAL: \$665**

- Backflow testing: \$300, once per year
- Carbon filter replacement: \$55, once per year
- 5 micron filter: \$28, four times per year
- 20 micron filter: \$37, four times per year
- 4 micron 10" lavatory filters: \$25, twice yearly

### *Maintenance process:*

- Once a month a water sample is sent to Missouri Department of Natural Resources for testing. The entire Center's filters have to be replaced every three to four months, the carbon filter has to be replaced once yearly, and the end of line filters at the lavatories are replaced every six months.
- The cistern that captures the rainwater has to be chlorinated or shocked once a year and restarted with a minimal amount of well water added to get the system back on line. The shocked water is then de-chlorinated before use in the building.
- There are two backflow preventers that must be tested once a year by a certified plumber.

## BLACKWATER TREATMENT

Solid nutrients are collected from toilets and processed in a self contained composter where they are broken down through aerobic biological conversion to a composted solid nutrient. The converted liquid nutrient and composted solid nutrients are then used in the landscaping and the organic vegetable garden, which produces food for human consumption, creating waste that can be processed in the building to start the cycle again.

### *Hard Costs:*

#### **TOTAL: \$115,000**

- Composting toilets: \$80,000
- On-site septic: \$35,000

### *Annual cost to maintain:*

N/A

### *Maintenance process:*

The team had to buy a special pump for the blackwater tank. It gets pumped roughly once every three months dependent on usage of the composting toilet system.

## GREYWATER TREATMENT

Water that is used in the sinks is collected in a greywater conversion tank, after which it is dispersed into an engineered greywater system within the landscape.

### *Hard Costs:*

#### **TOTAL: \$50,000**

- Irrigation system: \$25,000
- On-site greywater system: \$25,000

### *Annual cost to maintain:*

N/A

### *Maintenance process:*

The greywater treatment system is simple, and only includes a pump, filter, dosing tank and distribution manifold in a planted raised bed. Some plant maintenance and pruning is occasionally needed, and pumps may need to be replaced eventually. The filters are cleaned if the system ever clogs.

## UTILITIES

The project does not currently pay any utility fees.





# ECO-SENSE HOME

VICTORIA, BC | CANADA



## SIZE

2,150 SF

## TYOLOGY

SINGLE FAMILY HOME

## TRANSECT

L3

## CLIMATE ZONE

COLD NORTH

## DESIGN INCLUDES

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater reuse
- Composting toilet(s)
- On-site blackwater treatment
- On-site greywater treatment

## TOTAL COSTS

HARD: \$44,466

SOFT: UNKNOWN

## ROI

UNKNOWN

## KEY DRIVER

SELF-SUFFICIENCY

The Eco-Sense home is a multi-family residence consisting of two units to house six people. The home is a two-story load bearing cob building, with living roofs, potable rainwater collection, greywater reuse system, batch commode composting toilets, solar PV, and solar hot water. It is also 95 percent food independent.

Eco-Sense was the first international certified Living Building Challenge project. It received Petal Certification in 2010. All the systems were chosen in an effort to demonstrate that the team could self-provision their water and food, and manage all waste within the ecological boundaries within which the home resides. The home was designed so that there was no line that separated the house and the inhabitants from the ecosystem. Everything the ecosystem offered up was deemed as beneficial, be it rain, snow, wind, sun, cold or heat.

**“The ROI is one that we look at under a different capital than financial. We see the resiliency in the system. This security is well worth it.”**

Ann and Gord Baird,  
Residents

# FINANCIAL DETAILS

## RAINWATER TO POTABLE

Rainwater is collected and filtered by the 2,000 square foot living roof and then stored in cisterns.

The roof is layered with a non-fire-retardant EPDM, food grade polypropylene non-woven geotextile, horticultural Perlite, another layer of non-woven geotextile, coir mat, and three inches of pumice and leaf mulch. The water is pumped through a JUDO Profi 50 micron filter, then a 10 micron filter, a 1 micron carbon block, and finally a 0.5 micron ceramic filter before it reaches the house.

### *Hard Costs:*

10,000 gallon cistern and filtration: \$16,000

### *Annual cost to maintain:*

**TOTAL: \$350**

- Filters: \$200 (includes non-potable system)
- Testing: \$150

### *Maintenance process:*

- Yearly water testing
- Replace the carbon media with a refillable cannister
- Clean and sterilize the ceramic filter
- Inspect and clean pre-filter monthly
- Flush JUDO Profi filter monthly

## RAINWATER TO NON-POTABLE

The rainwater to non-potable system pulls water from the same cisterns as above, but is only filtered to 50 microns via a reusable pleated cellulose sediment filter. The water is pumped to hose bibs and outside irrigation.

### *Hard Costs:*

**TOTAL: \$16,200**

- NSF 61 HDPE Tanks (4): \$6,700
- Pumps: \$2,100
- Filtration Tanks: \$2,900
- Piping: \$2,000
- Electrical feeds: \$2,000
- Aerator: \$500

### *Annual cost to maintain:*

N/A\*

*\*Filter replacement cost is included in rainwater to potable section, above*

### *Maintenance process:*

- The irrigation system requires the removal and cleaning of the pleated filter once per month during irrigation season in the summer, and the system is bypassed in the winter
- Maintenance takes roughly ten minutes per month

## GREYWATER TO NON-POTABLE SYSTEM 1

All greywater from the house is filtered through a worm biofilter to remove fats and insoluble particulates, and to reduce BOD loading. The worm bin is situated subsurface, and consists of a 60 gallon water tank with screens.

### *Hard Costs:*

**TOTAL: \$2,300**

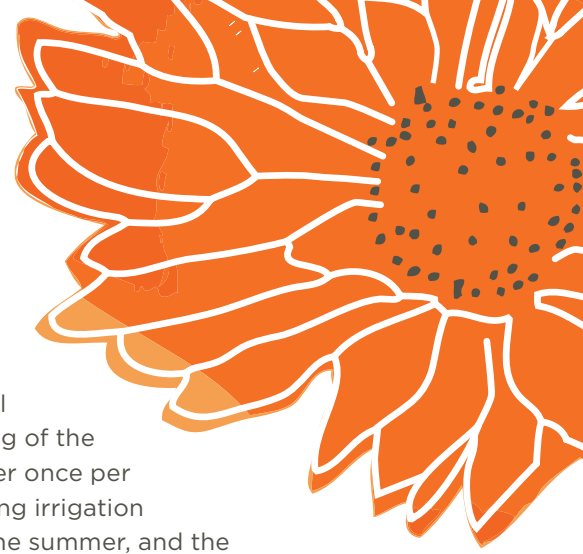
- Worm bin assembly: \$600
- Piping: \$1,700

### *Annual cost to maintain:*

N/A

### *Maintenance process:*

- Every two weeks the system is opened and additional mulch is added to ensure the presence of enough organics and bulking materials. During this interval, water flow is switched from System 1 to System 2 (see System 2, below).
- Tubing for irrigation is flushed once per year as part of yearly maintenance. This process takes approximately 10 minutes and is completed by the owners.



## GREYWATER TO NON-POTABLE SYSTEM 2

System 2 consists of a septic tank that was converted into a greywater treatment system. It is an 800-gallon, two chamber tank that overflows into a 200-gallon pump chamber.

### *Hard Costs:*

**TOTAL: \$6,600**

- Greywater tank: \$2,400
- Aerator, timer, diffuser: \$500
- Pump chamber: \$800
- Electrical: \$300
- Calming chambers: \$600
- Piping and valves: \$2,000

### *Annual cost to maintain:*

N/A

### *Maintenance process:*

N/A

## GREYWATER TO NON-POTABLE SYSTEM 3

System 3 consists of a kitchen sink diverter. Under the kitchen sink there is a simple knife valve that allows the water flow to be diverted into a bucket, or routed through to the main greywater feed to the two systems noted above. This system is used when washing garden harvests with sand or soil on them. The water is distributed in the garden.

### *Hard Costs:*

- Sanitary wye fitting to replace a 90° elbow: \$2
- Knife valve: \$17
- Bucket: \$7

### *Annual cost to maintain:*

N/A

### *Maintenance process:*

N/A

## COMPOSTING TOILETS

The composting toilet system consists of a Commode Batch (humanure bucket) with thermophilic processing, which services two toilets. Biomass is collected with the addition of a sawdust bulking agent used as a cover material.

Please note the prices below are based on the 2019 cost of these items - the original system was considerably less expensive.

### *Hard Costs:*

**TOTAL: \$3,340**

- Three Chamber Compost Processor: \$1,800
- Two toilet seat cabinets: \$1,200
- Ten HPDE buckets and lids: \$200
- DC Fans: \$70
- Dedicated tools (rake, hose): \$70

### *Annual cost to maintain:*

Cover materials (straw, hay, goat bedding, leaf mulch): \$200

### *Maintenance process:*

- Weekly servicing involves opening the active pile, depositing the contents, and rinsing and covering the pile with new covering materials. This process takes roughly 20 minutes.
- Yearly servicing involves remove contents from the oldest composter after two years to spread on the land. This process takes roughly one hour.

## UTILITIES

The home and working farm is not connected to any municipal water or wastewater system.





# DESERT RAIN

BEND, OR | USA



## SIZE

4,810 SF

## TYOLOGY

SINGLE FAMILY

## CLIMATE ZONE

HIGH DESERT

## DESIGN INCLUDES

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater reuse
- Composting toilet(s)
- On-site blackwater treatment
- On-site greywater treatment

## TOTAL COSTS

HARD: \$132,669

SOFT: \$260,764

## ROI

UNKNOWN

## KEY DRIVER

VALUE ALIGNMENT

Desert Rain is a residential compound located on the edge of an historic downtown neighborhood in Bend, Oregon. This project, comprised of five separate structures, has achieved Living Certification under the Living Building Challenge.

The focal point of the housing complex is a one-story residence with a stucco exterior, graceful rooflines and a striking curved wall which greets visitors on approach. The wall threads through the building and exits out the opposite side, near a walkway which connects this main residence to the two other residential buildings. In the words of owners Tom and Barbara Elliott, “Desert Rain is more than a home or compound for us—it is an outer expression of our inner values and beliefs—an effort to live in greater alignment with our core values in a life and world that is fraught with inconsistencies.”

**“What is it worth to eliminate externalized costs instead of passing those on to our children and grandchildren?”**

Tom Elliott  
Owner

# FINANCIAL DETAILS



## RAINWATER TO POTABLE

The building's potable rainwater collection system (the first potable system approved within an Oregon municipality) begins with 7,000 square feet of roof area from structures in the compound feeding into a 35,000 gallon cistern. Rainwater passes from the roof through a stainless steel gutter screen into a small gravel filter (in place of the code-mandated first-flush diverter), then through a 20 micron filter into another cistern. From this cistern, the water passes through two 20 micron filters and a UV system as it is pressurized to feed the various buildings.

**Hard Costs:**  
\$35,539.34

**Soft Costs:**  
\$105,948.51

**Annual cost to maintain:**

**TOTAL: \$370**

- New filters: ~\$100, three times per year
- UV bulb: \$70

**Maintenance process:**

- Filters changed approx. every four months
- UV bulb changed approx. once per year

## GREYWATER REUSE

The building's Tier II graywater system was also the first system of its type approved by the State of Oregon. It collects water from sinks, laundry, and showers and distributes it to a 1,500 gallon primary tank to remove the solids. The water is then transported to a 500 gallon lift station, then to a 600 square foot underground constructed wetland bioreactor, where it is treated by the natural aerobic and anaerobic bacteria. From the wetland, the water is conveyed to a 1,000 gallon treated water tank and is pumped back to a 5,000 gallon storage tank. 100% of treated graywater is used for subsurface irrigation, drip irrigation, and water features.

**Hard Costs:**  
\$26,051.09

**Soft Costs:**  
\$105,948.51

**Annual cost to maintain:**  
\$260

**Maintenance process:**

- Annual Department of Environmental Quality report filed in January, water samples must be processed
- Monitor tank levels
- Pumps are maintained and replaced as needed (approx. one pump per 5 years)
- Irrigation system is blown out in the fall to avoid broken pipes from freezing weather

## BLACKWATER TREATMENT

The compound's blackwater treatment system is designed to bring all waste from the dwellings to a central Phoenix composting unit using vacuum flush toilets. Liquids, including dishwasher wastewater, are evaporated using a solar hot-air assisted evapotron.

**Hard Costs:**  
\$71,078.68

**Soft Costs:**  
\$48,866.71

**Annual cost to maintain:**

**TOTAL: \$400**

- Wood shavings: \$150 per year
- Equipment maintenance: \$250 per year
- Labor, including stirring and adding chips weekly and removing compost once per year (20 hours per year, completed by residents)

**Maintenance process:**

- The composter must be stirred and supplemented with a bucket of wood chips once per week, and the pile must be leveled once per month. The owners add fly spray/powder as needed.

## UTILITIES

The team was required to pay connection fees to the local utilities, amounting to \$2,520.78. They did not receive any discount to account for the lack of use. They also pay a yearly water connection fee \$292.80 and yearly sewer-stormwater connection fee of \$413.16, the minimum charge for required hook-up. Conventional utility charges would be higher based on water usage.



# BROCK ENVIRONMENTAL CENTER

VIRGINIA BEACH, VA | USA



Photo by Prakash Patel, courtesy of SmithGroup

## SIZE

10,518 SF

## TYOLOGY

OFFICE + EDUCATION

## CLIMATE ZONE

HUMID SUBTROPICAL

## TRANSECT

L1

## DESIGN INCLUDES

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater reuse
- Composting toilet(s)
- On-site blackwater treatment
- On-site greywater treatment

## TOTAL COSTS

HARD: \$170,000

SOFT: UNKNOWN

## ROI

0 YEARS

## KEY DRIVER

LEADERSHIP

The Chesapeake Bay Foundation (CBF) fights for effective, science-based solutions to the pollution degrading the Chesapeake Bay and its rivers and streams. For more than 50 years, CBF has worked to Save The Bay - a national treasure.

**“We cannot relax in our efforts to make a positive difference.”**

Chris Gorri  
Brock Center Manager

The Brock Environmental Center serves as CBF’s hub in Hampton Roads, implementing and supporting education, advocacy, and restoration initiatives. The building provides offices for CBF and partner groups, with meeting spaces and a 90-seat conference room. It has become an important part of the community, hosting conferences, public discussions, community events, and CBF’s national award-winning environmental education programs.

With this project, CBF put into practice the values it champions. The Brock Center goes well beyond simply doing less harm to the environment than a typical building. It proves that architecture can create a positive, regenerative impact on both the environment and all living communities.

# FINANCIAL DETAILS

## RAINWATER TO POTABLE

The Brock Environmental Center utilizes a rainwater harvesting system to meet the entire water supply needs (both potable and non-potable) of the facility. The rainwater storage, treatment, and distribution system utilizes water filtration and disinfection systems capable of meeting all the performance requirements of the Virginia Waterworks Regulations and the EPA federal Safe Drinking Water Act including the Surface Water Treatment Rule, the Interim Enhanced Surface Water Treatment Rule, the Long Term 1 Enhanced Surface Water Treatment Rule, and the Long Term 2 Enhanced Surface Water Treatment Rule.

### *Hard Costs:*

**TOTAL: \$81,000**

Rainwater filtration skid: \$48,000

Water cistern with ozone injection: \$20,000

Attic level pressure tank: \$13,000

### *Annual cost to maintain:*

\$11,000 per year, down 50% since 2015 (first year of operation)


### *Maintenance process:*

- CBF hired MSA, P.C., a local Virginia Beach firm, to serve as the Systems Class IV Water Works operators and perform monthly required sampling and inspections that ensure the treated rainwater meets Federal regulations.
- The on-site Brock Center Manager conducts the daily monitoring tests, which include testing for chlorine residual and temperature, as well as filter monitoring and replacement.

## BLACKWATER TREATMENT

The Center uses waterless Clivus Multrum composting toilets for sewage treatment. The building contains five gravity-fed compost bins located within the grade-level mechanical rooms, each with an annual capacity of 25 ft<sup>3</sup> for a total volume of 125 ft<sup>3</sup>.

Compost is collected from the individual composters. When satisfactorily broken down, the material is buried in approved subsurface sites, in accordance with current local health department regulations that do not allow that waste to be surface applied. Leachate from the bottom of the compost bins is pumped to a separate leachate tank sized to hold 3 months' worth of leachate.



A local sewage contractor has been contracted by CBF to haul the leachate to the Nansemond Waste Treatment Plant for treatment using a struvite reactor. The reactor injects leachate with a catalyst that causes the nutrients in the leachate to precipitate, forming struvite, a commercially viable fertilizer.

### *Hard Costs:*

Composting toilets: \$64,000

### *Annual cost to maintain:*

\$1,800 per year

### *Maintenance process:*

- According to Brock Center Manager Chris Gorri, the composting toilets are easy to maintain and have minimal costs associated with them.
- Each bin needs to be raked a few times each month, more often if large events or meetings take place during that time.
- Wood shavings are added by guests and during monthly maintenance.
- The sanitary leachate is stored in a tank on site and pumped out quarterly by a sewage contractor who brings the liquid to be processed and turned into fertilizer.

## GREYWATER TREATMENT

Greywater from sinks and dishwashers is stored in a 1,000-gallon chamber on site. The greywater is pumped to a garden that uses native plants to filter pollutants and impurities, and this naturally filtered water replenishes the underground aquifer.

### *Hard Costs:*

On-site greywater system: \$25,000

### *Annual cost to maintain:*

N/A

### *Maintenance process:*

- Monitor the pumps to ensure that they are working.
- Check the alarm and keep the the greywater gardens weeded.

# FINANCIAL DETAILS

## UTILITIES

CBF's Brock Environmental Center pays minimal service fees to local utility companies in order to cover the cost for the Center to be tied to the City's water and sanitary sewer. CBF would be charged if these back-up systems were ever used in case of an emergency.

### *Stormwater fee:*

\$1,300 per year: This fee is charged in order to help the City upgrade their waste and storm water treatment systems. CBF could have asked for an exemption from this, but chose not to do so as the fee contributes to their mission to "Save the Bay." CBF wanted to do its part by showing others how important these upgrades are to the Chesapeake Bay and set an example by paying the fee.

### *Water Service fee:*

\$150 per year: Service charge to be connected to the municipal water supply for fire suppression at the Brock Center.

### *Sewer Service fee:*

\$700 per year: Service charge to be connected to the sanitary sewer system, which is only in place for a back-up if the leachate holding tank were to overflow.

### *Line tap fee:*

In addition, the City of Virginia Beach charges a "line tap fee" to connect to their sanitary sewer system. The commercial fee that was originally quoted to CBF was \$382,000. This cost was based on the volume of sewage that a conventional building would discharge into a treatment facility, resulting in an increase to existing service.

CBF applied for a waiver, providing information on its systems and the amount of potential discharge that could be sent to the municipal facility for treatment. The team demonstrated that there was a plan to treat all the waste on site, or take it off site for treatment, and that there would be no usage of the municipal sewer since flushable toilets were not being used and greywater was treated on site. The permitting agency, Hampton Roads Sanitary District, agreed, and only charged CBF \$1,900 for the connection fee. In doing so, the project saved over \$380,000, which more than covered the cost of the on-site water system, resulting in an immediate return on investment.

## RETURN ON INVESTMENT

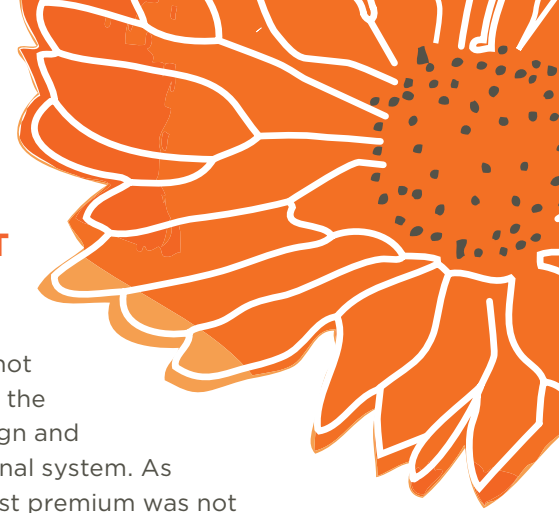
An official life-cycle cost assessment was not provided, nor did the design team design and price a conventional system. As such, the hard cost premium was not determined. From an operating perspective, had the Chesapeake Bay Foundation not invested in these alternative sustainable systems, the annual cost to CBF would have been approximately \$3,000 per year. CBF would also incur higher monthly costs associated with connection to the municipal systems.

In addition to the positive impact on the environment and the Chesapeake Bay, and by reducing waste to sewage treatment plants, the composting toilets and greywater system have already paid for themselves through the \$380,000 discount in sewer connection fee that was given during construction. Today, CBF pays service fees that total approximately \$850 per year (not counting the stormwater fee), a municipal cost savings of \$2,150 per year, which CBF uses to offset the additional costs of treating the rainwater for potable uses.

## ADDITIONAL THOUGHTS

The design team believes that project costs reflect a client and design team's priorities. The team prioritized achieving net-zero energy, water, and waste as well as full LBC certification. When cost premiums were encountered, they were offset by other design approaches like using less expensive finishes. CBF also made the decision to pay a premium if they felt the item was critical to fulfilling the goal of pushing the boundaries so that it would be easier for others to accomplish this in the future.

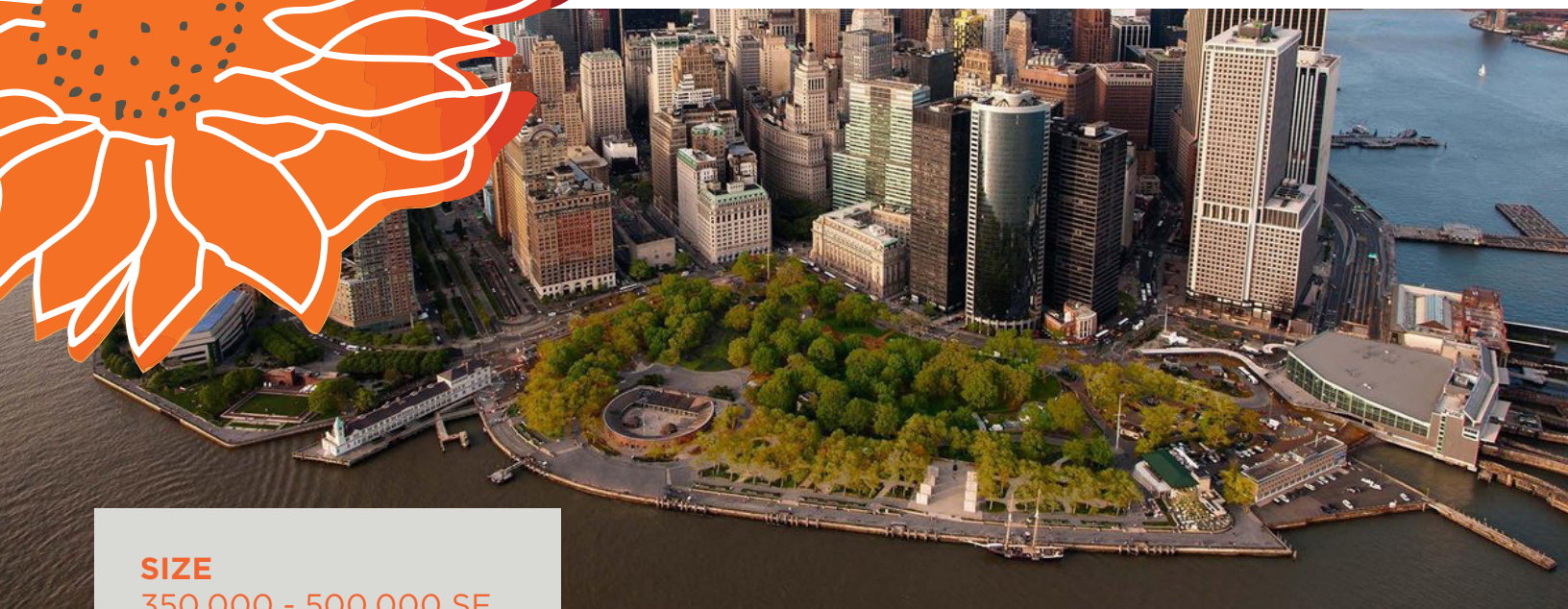
The co-benefits to the community include an overall resilient design approach. The project stores a six- to seven-week supply of untreated rainwater in its cistern and a week's supply of treated potable rainwater in the attic storage tank. As such, CBF is modeling how to supplement the community's water supply in the event of a disaster that impacts municipal water supply.





# BATTERY PARK CITY

NEW YORK CITY, NY | USA



## SIZE

350,000 - 500,000 SF

## TYOLOGY

DISTRICT-SCALE  
MULTIFAMILY

## CLIMATE ZONE

HUMID SUBTROPICAL

## TRANSECT

L6

## DESIGN INCLUDES

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater + blackwater reuse
- Composting toilet(s)
- On-site blackwater treatment
- On-site greywater treatment

## TOTAL COSTS

HARD: \$1,200,000

SOFT: \$232,000

## ROI

3 - 10 YEARS

## KEY DRIVER

RESILIENCY

Battery Park City refers to the 92 acre redevelopment area under the control of the Battery Park City Authority (BPCA) of New York City. The BPCA adopted a mission of sustainable urban development for the redevelopment of this

land, which included water conservation objectives. Natural Systems Utilities (NSU) designed, built and currently operates and maintains six onsite water treatment and reuse systems that have served eight buildings in Battery Park City since 2003. Battery Park City's district-scale on-site water reuse initiative was motivated by the City's larger green building goals, including reducing the consumption of water associated with building construction and operation, protecting the surrounding environment from the potential damages caused by the development, and creating green, comfortable, and safe living environments for the community.

**“These systems have consistently achieved a 50 percent reduction in water consumption and a 60 percent reduction in wastewater discharge.”**

Natural Systems Utilities

# FINANCIAL DETAILS

## BLACKWATER TO NON-POTABLE

The Battery Park district's grey and blackwater to non-potable system consists of a membrane bioreactor (MBR) followed by a multiple barrier approach for disinfection. The bioreactor is an activated sludge system with membranes that have an effective pore size smaller than 0.1 microns. The disinfection system consists of an ozone generation and contacting system, used for oxidation and color removal; followed by an ultraviolet light system for additional disinfection and sodium hypochlorite addition.

Effluent water quality meets strict reuse standards and is reused for toilet flushing water, cooling tower makeup water, irrigation, maintenance purposes, and laundry. Approximately 40 percent of the surplus raw wastewater and residual biosolids are discharged to the sewer system. Automatic potable water fill valves at the water storage tanks ensure an uninterrupted supply.

An NSU-patented thermal heat recovery system converts the water reuse system at one building in Battery Park City into a distributed energy generator, allowing it to operate at net zero or net positive energy at flow rates above 25,000 gpd. A gas absorption heat pump, coupled with high efficiency heat exchangers, were installed to transfer thermal energy from treated wastewater (which enters the system at an average of 75° - 85° F) to building domestic water heating systems, reducing the amount of energy needed to heat the water (which is typically around 45° - 55° F).

### Hard Cost:

#### TOTAL: \$1,200,000

- Blackwater reuse system: \$1,000,000\*
- Thermal Heat Recovery: \$200,000

*\*Please note total hard costs for the water treatment and reuse system represented less than one percent of total building costs.*

### Soft Cost:

#### TOTAL: \$232,000

- Blackwater reuse system: \$120,000 (~1,000 hours)
- Thermal Heat Recovery: \$72,000 (~600 hours)
- Permitting: \$40,000<sup>+</sup> (~ 200 hours + fees)

*<sup>+</sup>Costs for permitting are unusually high given this was the first system of its kind installed in NYC with an ammonia based heat pump.*

### Annual cost to maintain:

\$75,000 - 100,000

### Maintenance process:

- Two operators visit the site two to three times per week for four hours per visit in order to run tests and ensure the equipment is functioning.
- Chemicals, equipment and electrical cost is also included in the number above, which is a part of NSU's Operations Contract with the building owners.

## RAINWATER TO NON-POTABLE

The buildings include a separate collection and treatment system for rainwater only. Collection tanks range from 8 - 10,000 gallons and treatment systems include different variations of filtration and disinfection. Treated water is only used for irrigation within most of the systems. Some of the systems include a connection between the rainwater treatment system and the blackwater system, allowing treated rainwater to be transferred and used for flushing/cooling depending on overall building demands.

Because NSU did not design this system, ILFI was unable to attain the relevant cost data.

## UTILITIES

Standard water and sewer connections were required and installed in these buildings at the time of construction. These buildings receive a Comprehensive Water Reuse Program water and sewer rate because of the water reuse systems, a 25 percent discount from base water and sewer rates, in addition to their naturally low rates from water and sewer use reduction. The New York City Department of Environmental Protection also offers a capital grant for up to \$500,000 for water reuse systems depending on their size. This grant also helped to offset the system cost.





# ARCH NEXUS SAC

SACRAMENTO, CA | USA



## SIZE

8,252 SF

## TYOLOGY

OFFICE

## TRANSECT

L4

## CLIMATE ZONE

MEDITERRANEAN

## DESIGN INCLUDES

- Rainwater for potable use
- Rainwater for non-potable use
- Greywater reuse
- Composting toilet(s)
- On-site blackwater treatment
- On-site greywater treatment

## TOTAL COSTS

HARD: \$360,000

SOFT: \$80,000

## ROI

UNKNOWN

## KEY DRIVER

EDUCATION +  
DEMONSTRATION

In January of 2017, Architectural Nexus moved in to its newly renovated office in Sacramento, CA, hoping to be the first Living Building certified in California. In 2018, this hope became a reality. In response to California's recent and recurring droughts and energy crises, Arch Nexus designed the building (dubbed Arch Nexus SAC) to lay a framework for how to operate in such conditions. By looking to nature for its concept and looking to place for its roots, the project is an educational and community asset for California. Arch Nexus SAC opens its facilities up to the community for educational tours so that anyone can see the building and learn about the design, the systems, and the operations. The hope is that tour participants will leave motivated to employ regenerative strategies in their own workplaces as well as at home.

**“It was worth every penny, and we would do it again.”**

Kenner Kingston  
President, Arch Nexus



# FINANCIAL DETAILS



## RAINWATER TO POTABLE

Rainwater runs off the roof into two large cisterns sunk into the ground and secured with helical piers. The system uses a Netafim microbial filter followed by a Blue Future sand filtration system with Aquatec recirculation pump and a Viqua UV filter. The rainwater system currently provides water for Arch Nexus SAC's irrigation system, and will provide potable water for its sinks, showers, and dishwashers once a permit is acquired from the state of California.

### *Hard Costs:*

**TOTAL: \$110,000**

Rainwater cisterns: \$60,000

Potable water treatment & storage: \$50,000

### *Annual cost to maintain:*

\$0\*

### *Maintenance process:*

- The inside of the vortex filter is cleaned in the dishwasher once a month during the rainy season and once every three to four months during the summer.
- Roof drains are cleaned every other day during the rainy season. During the summer (when leaves are not falling) they are cleaned once every other week. Alternative low-maintenance roof cleaning methods include wet vacuums, blow bags, and simple drain snakes.
- The area drain is cleaned once every 6 months or as needed.
- The sensor on top of the tank needs new batteries once a year.

## ON-SITE GREYWATER REUSE

The greywater system receives the water from the building's sinks, showers and dishwasher, and treats it for reuse. Greywater treatment follows the same process as potable water treatment (see above) with the exception of additional pretreatment measures. Pretreatment includes a basket filter to remove floating debris and a roughing filter to remove the majority of suspended solids and turbidity. A slow sand filter, carbon block filter, UV light disinfection unit, day tank and circulation pump are then incorporated, as described in the potable water system to produce high-quality treated greywater.

Treated greywater is reused within the building for toilet flushing and living wall irrigation. With all systems operating as designed, all greywater evaporates on site without need of an active sanitary sewer connection.

### *Hard Costs:*

**TOTAL: \$100,000**

- Living wall: \$50,000
- Greywater treatment & storage: \$50,000

### *Annual cost to maintain:*

**TOTAL: \$2,272\***

- Replacement of plants: \$1,800
- Fertilizer: \$200
- Microbes: \$20
- Carbon filters: \$180
- Bubblers: \$72

### *Maintenance process:*

- The entire system needs to be drained and cleaned roughly once per quarter, a process which takes a team of four people roughly three hours.
- Microbes have to be added to every filter once per week.
- Sump pump needs to be vacuumed out with a shop vacuum once per week.
- Carbon filter needs to be changed at least once every 2 months (varies based on the water clarity).
- Bubblers in the tank must be replaced annually.

## COMPOSTING TOILETS

The project uses Phoenix composters with wall mounted JETS vacuum flush toileting system. The in-ground leachate tank is produced by Oldcastle.

### *Hard Costs:*

Composting toilet + underground leachate vault: \$150,000

### *Annual cost to maintain:*

Pyrethrum spray: \$33\*

*\*Labor is included under the role of an existing maintenance staff position and does not incur additional cost for Arch Nexus.*

## COMPOSTING TOILETS, CONTINUED

### Maintenance process:

- Periodically, the cover of the composting unit must be removed from the motor and the macerator to make sure nothing is stuck. Alternatively, the system can be checked via the small “viewing window” on the macerator side, eliminating the need to take off the cover.
- Donated wood shavings are added to the composting toilets as a bulking material.
- Pyrethrium spray is used to control fungus gnats—one bottle costs \$33 and lasts all year.
- Jet pumps are checked for scaling every three months and descaled annually if needed with mild soap and water.

## UTILITIES

Because this was an adaptive reuse of an existing building, there were existing water and sewer connections. The team pays roughly \$2,000 per year for their sewer connection, which they have never used, in order to support and improve the municipal system.

