The Bullitt Center Composting Toilet System
A White Paper on Lessons Learned

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Introduction

The Bullitt Center was designed to show what's possible. It is exploring scores of new ideas in an effort to push architects, engineers, developers, and bankers to ever-greater levels of environmental performance. Before the Center was built, for example, every developer interviewed by the project team asserted that it would be impossible to generate as much electricity from sunlight striking the roof of a six-story office building in Seattle, WA as the building and its tenants would need. However, calculated on an annual basis, the Bullitt Center has been a net-positive energy building since its opening in 2013.

Once something exists, no one can claim that it is impossible.

"The Bullitt Center is a giant science experiment," said Denis Hayes, CEO of the Bullitt Foundation and leader behind the project. "We integrated lots of bleeding-edge technologies. If everything had worked perfectly, that might have meant we hadn't been bold enough."

It is in this context of experimentation and learning that the Bullitt Center decided to remove the composting toilet system from the building, replacing it with a highly water-efficient vacuum flush system connected to the municipal sanitary sewer system.

This paper offers insights into this decision, as well as lessons learned, to inform other teams as they consider composting toilet systems in their own projects.

Background

When the Bullitt Center design team began its work, the Living Building Challenge 2.1, administered by the International Living Future Institute (ILFI), included two Imperatives under the Water Petal: Imperative 05, Net Zero Water and Imperative 06, Ecological Water Flow. Per Imperative 06, "One hundred percent of storm water and used project water discharge must be managed onsite to feed the project's internal water demands or released onto adjacent sites for management through acceptable natural timescale surface flow, groundwater recharge, agricultural use or adjacent property needs."

In part, this meant that projects were required to manage and treat their own water discharge (e.g., wastewater from toilets, sinks, and showers) on site. ILFI has never prescribed the systems or technologies needed to accomplish this requirement. Instead, ILFI allows project teams to determine the best solution, based on the project's climate, program, size, and surrounding ecological, human, and code context, as well as other factors.

The project team working on the Bullitt Center decided to use a combination of an onsite greywater system to treat the water discharge from sinks and showers and an onsite composting toilet system to treat the human waste from toilets and urinals. To the project team's knowledge, a composting system for a six-story building had never been attempted anywhere in the world.

The current Living Building Challenge 4.0 allows three different options for managing a project's wastewater:

1. Onsite treatment.
2. Connection to biologically based municipal sanitary sewer systems that meets certain environmental and health criteria.
3. Handprinting, which is an option that allows projects to connect to any municipal sanitary sewer system if the project offsets at least the same amount of water discharge by investing in efficiency measures for another property served by the same municipal system, such that the total amount of sewage sent to the municipal system by both projects combined remains the same or is less after the project has been built.

Even with a variety of compliance options available, many project teams focus their design and engineering efforts on onsite treatment options, including composting toilet systems, because onsite approaches reduce the burden on municipal systems (which in many cases are overtaxed and failing), and because these onsite approaches often provide greater ecological benefits, including the potential for nutrient recovery.

To help project teams explore the benefits and costs of composting systems, this paper was developed to provide insights from Bullitt Center's experience. By describing a project that installed a composting toilet system and operated it in a multi-tenant commercial building setting for nearly seven years, this paper captures the key toilet-related lessons from the Bullitt Center.

It is important to emphasize that PAE, the mechanical, electrical and plumbing engineering firm for the Bullitt Center, is currently designing and installing a composting system in its own new 5-story office project, the PAE Living Building, in Portland, Oregon. PAE's in-depth knowledge of the Bullitt Center's experience informed the development of its own building, which incorporated many of the lessons shared below. Their experience also provided valuable input to this paper. There are many other projects using composting systems as well.

Rationale for a Composting Toilet System

According to Jason F. McLennan, founder of the International Living Future Institute and creator of the Living Building Challenge, the purpose of the Water Petal is to "shine a light on the things that are fundamentally flawed and need to be fixed to have a regenerative future." In cities around the world, some of the largest budget lines are connected to moving water and human waste. Municipal systems frequently fail to treat chemicals, from the pharmaceuticals we consume to industrial poisons mixed into the sewage stream. This creates environmental and public health problems. In addition, huge amounts of energy are used to move water and waste. For example, in California, water-related energy use consumes 19 percent of the state's electricity, 30 percent of its natural gas and 88 billion gallons of diesel fuel every year[1].

[1] Cascadia Green Building Council. TOWARD NET ZERO WATER: BEST MANAGEMENT PRACTICES FOR DECENTRALIZED SOURCING AND TREATMENT, March 2011. p.12. https://living-future.org/wp-content/uploads/2016/11/Toward_Net-Zero_Water.pdf

There are several important reasons to consider a composting system in new construction. When well designed and operated efficiently, certain composting systems have the potential to advance the following objectives:

- **Dramatically reduce water use.** The Bullitt Center used approximately 1 gallon of water per square-foot of floor area per year, which is approximately 95 percent less than the average commercial office building. While there are several reasons for this dramatic reduction in water usage, the primary one was the composting toilet system. Even an efficient standard toilet uses 1.28 gallons per flush, with modern automated sensors occasionally flushing multiple times per visit to the stall. By contrast, the Bullitt Center foam flush composting toilet system used only one or two cups (depending upon how long the person remained seated on the toilet). The new vacuum flush toilets at the Bullitt Center will use only 7 cups (0.45 gallons) per flush. This is still 70% less than a standard 1.6 gallon-per-flush code-compliant toilet, but a significant increase from the foam flush.

- **Return nutrients to the land.** Instead of contributing to water pollution, compost used as fertilizer can reconnect the nutrient cycle. It does not contain industrial waste, but it can contain birth control hormones, antibiotics, and dish washing detergent. Some viruses and bacterial infections can also survive composting and require supplementary treatments. Treatment beyond the ambient-temperature composter may be necessary before poop can be used as fertilizer.

- **Reduce energy use.** When the compost can be used locally, composting systems can use significantly less energy than municipal sewage systems. However, if the compost must be trucked a long distance, the fuel used can more than offset the energy savings. Compost from the Bullitt Center had to be hauled 52 miles round-trip, in a loaded diesel truck and trailer, ten times a year.

- **Reduce aerosols in the bathroom.** The Bullitt Center's composting toilet system maintained negative pressure to draw air down through the toilet, exhausting it out the roof of the building. This was intended to both aerate the compost pile and mitigate smells in the bathroom, since there is no water trap in a compost toilet. A possible side benefit is that there is no aerosol plume associated with flushing the toilet, thus potentially reducing transmission of microorganisms.

- **Reduce burden on over-taxed municipal wastewater systems.** In communities with combined sanitary and stormwater sewers, the systems can be over-loaded during heavy rain events (as happened, for example, in Seattle recently). When this occurs, raw sewage is poured directly into nearby bays, lakes and rivers where storm sewers ordinarily drain. Composting waste on-site stops that waste from entering into the combined sewer system.

Lessons Learned

When it opened in 2013, the Bullitt Center included the Phoenix Composting Toilet System. Lowered down the elevator shaft before the car was installed, the 10 composters were located in the basement of the building. The Bullitt Center's website describes how the composters work.

During their years at the Center, the composting toilets were used almost 200,000 times. A highlight of the regular building tours, the composting toilets were media darlings covered by *CNN* and *The Los Angeles Times*, among many others. On any given day, 100 or more tenants and visitors used the toilets.

The Bullitt Center raised the profile of composting toilet systems and also served as a proof point for new construction projects considering the system. In addition to the PAE Living Building mentioned earlier, the Arch Nexus building in Sacramento, the City of Santa Monica City Hall, and the Kendeda Building for Innovative Sustainable Design at Georgia Institute of Technology, as well as many others, installed composting systems.

Collectively, the Bullitt Center team learned a great deal about designing, operating and maintaining a composting system in a multi-tenant commercial building. Following below are the key lessons from this experience.

- **Provide enough space to access all sides of the composters.** At the Bullitt Center, ten composters were located in a room that just fit them, preventing access to three sides of most of the composters. As a result, it was extremely difficult to inspect the composters and make needed repairs.

- **Provide enough ceiling space to access composter for routine maintenance.** At the Bullitt Center, there was just enough height in the composter room to fit the composters and make the piping connections. Access to the top of the composters was suboptimal for the routine weekly maintenance that was required.

- **Include a system to distribute waste among composters.** At the Bullitt Center, there was a direct connection between specific toilets and composters. Because some toilets receive much more use, the result was an uneven load of compost across the ten units. This caused inefficiencies, particularly when it came to emptying the composters. Rather than filling a truck by emptying all ten at once, the Bullitt Center had to empty the composters at different times. As an example of how to mitigate this issue, the PAE Living Building is using a vacuum waste manifold system to evenly distribute waste among the units. Unisex bathrooms could also mitigate the problem of uneven loading if tenants' employees identify as predominantly of one gender.

- **Use more composters to balance load.** Related to uneven load, the Bullitt Center would have benefitted from more composting units. This would have reduced the load to any one composter, which would have increased the time between emptying the composters.

- **Plan ahead for the ultimate use of the compost.** Because the Bullitt Center is located in a dense urban neighborhood, compost was removed offsite to a secondary treatment facility where it was processed into a product for use in gardens. Because of the relatively small number of units and uneven loading, the Bullitt Center frequently had to empty units as they became full, even though the others were not ready. The result was a partially loaded truck moving waste 52 miles to the treatment facility, which increased the carbon emissions and other air pollution impact of the composting toilet system overall.

- **Develop a strategy to maintain the system over time.** In a hot real estate market like Seattle, there was frequent turnover in building engineers during the Bullitt Center's first seven years of operations. The subcontractor insisted on rotating its engineers among its buildings, and the engineers themselves sought to move on to high-rise buildings. However, managing the composting system required expertise and experience that was not applicable to any other building in the city, and the turnover caused discontinuities in training and maintenance. In the end, the Bullitt stopped contracting with its outside vendor and directly hired an excellent permanent engineer.

- **Plan for system resilience.** In the Bullitt Center, a system of fans and ducts moved air from the bathrooms, down the toilets, through the composters, and ultimately out the fan on the building's roof. Creating continuous negative pressure through the system compensated for the lack of a trap in the composting toilet. Without the fans, smells from the composters moved quickly into the bathrooms and office spaces, which was not popular. If the power to the building was cut by a storm, or when the fans needed maintenance, indoor air quality declined very rapidly. While battery backup systems were evaluated at the outset of the project, the team decided to delay until the technology had advanced. With today's superior batteries, the team would make a different decision.

- **Consider a vacuum flush system to improve user experience.** Vacuum flush toilets can be used with composting toilet systems. While they increase water use over foam flush toilets, they still use significantly (65-75%) less than a typical low-flow toilet, and they can rely on greywater (not potable water) for flushing if a separate system is built into the building. Notably, the vacuum flush system can also improve the user experience by keeping the bowl much cleaner than the foam flush system. The Bullitt Center also experienced far greater maintenance issues with the foam flush system than it had anticipated. Fully one-half of all the building engineer's time on-site was spent dealing with problems in the composters or the toilets, and the work was often quite unpleasant.

- **Design the composting system for good drainage.** Liquid waste was diverted from the composting units into leachate tanks. But because the composters sat directly on the floor at the Bullitt Center, the outflow pipes were slightly above the bottom of the composter. As a result, drainage was poor, with leaks developing at gaskets over time. The use of wood shavings – intended to help dry the compost pile – exacerbated the problem, as they clogged the drain holes at the bottom of the units (although wood chips proved better than wood shavings). These small leaks of the non-composted leachate

were worrisome from a health perspective. The odor was also a negative for any building tour that encountered a leaking composter.

- **Design for urine diversion** A urine diversion system helps keep liquids out of the composters and also provides the opportunity to recover valuable nutrients in urine that can be turned into fertilizer.

- **Expect higher system maintenance costs.** Even with the water savings, it costs more to manage a composting toilet system than to have a conventional sewer hookup. Municipal sewer systems are heavily subsidized by federal, state and local governments and financing is typically by tax-free municipal bonds. In contrast, the full cost of operating a composting system falls on the landlord and tenants. So, although there can be many public benefits to composting toilets systems over municipal sewage systems, their capital and operating costs will be higher with the current generation of technology.

- **Consider the appropriate scale.** Given the work involved in maintaining a composting toilet system, a campus or district scale will generally make more sense than managing a system in a single building. The International Living Future Institute encourages this through scale jumping.[2] With a vacuum flush system, where waste can be transported over a distance, there's potential to achieve economies of scale.

- **Pay attention to public policy.** Just as it is impossible to solve the climate crisis solely through changes in individual behavior, we will not be able to fix the world's sewage crisis on a piecemeal basis, one building at a time. There is no compelling reason why industrial wastes should be mixed with sanitary sewage—knowing that heavy metals and toxic compounds will render the resulting sludge unusable. There is no good reason why storm sewers should be combined with sanitary sewers—knowing full well storms will cause raw sewage to be flushed into public waterways. Governments have spent trillions of dollars building sewage systems that don't meet our needs. Demand better of your elected leaders.

Conclusion

The Bullitt Center can be thought of as a collection of science experiments. It sought to test what was possible in a bold effort to do everything right. By design, the project pushed the envelope.

Although the Bullitt Center made the decision to replace its composting toilet system, other projects have learned from its experience and are conducting their own experiments with new, improved systems. Vacuum flush systems, load distribution, more space to access composters and other strategies are being used to improve reliability. Through the lens of experimentation, the Bullitt Center successfully advanced the concept, breaking ground for projects that followed.

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[2] Scale Jumping is an overlay in the Living Building Challenge that allows multiple projects to operate cooperatively – sharing infrastructure as appropriate and allowing for fulfillment of requirements as elegantly and efficiently as possible.

Although composting toilets have existed in simple forms for thousands of years, and many are in use around the world today, the devices have not profited much from modern science and technology. None of the major toilet manufacturers in the industrial world make composting toilets. They remain a niche technology, identified in many people's minds with those who took the *Whole Earth Catalog* seriously.

However, the potential benefits of elegant, sophisticated, right-sized composting systems would be very real. With biomimicking design, quality manufacturing, proper installation and careful management, composting toilet systems can save significant water and energy, while also returning nutrients to regenerate soils. But this will never scale as long as every building has to start at ground zero to design its toilet system from scratch.

Although the removal of the Bullitt Center's composting toilet system was a disappointment, the team is pleased to have served as a proving ground for a better approach to treating human sewage in a dense urban environment. In addition, the engineering company with the most intimate knowledge of the Bullitt Center's system – PAE – is moving forward with a revised approach to composting toilets in its own new urban headquarters.

Hopefully this white paper will help other project teams evaluate tradeoffs and make better decisions as they consider whether and how to install a composting toilet system in their buildings.