BIOLOGY AND BUILDING—THE LIVING LEARNING CENTER AT WASHINGTON UNIVERSITY'S TYSON RESEARCH CENTER: A Journey on the Path to the Living Building Challenge

"In a time of drastic change it is the learners who inherit the future."
—Eric Hoffer

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INTRODUCTION

The result of equal parts serendipity, exploration, creativity, and the enduring persistence of a dedicated team of designers and its university client, Washington University's Living Learning Center, has quickly become a locus of sustainability. It is a deep green place filled with fresh air and daylight, an ongoing achievement in zero net waste, zero net water, and zero net energy design, a space that inspires higher learning about the natural world. The Center is also well on its way to certification as the first living building in the world.

BACKGROUND

Located in Eureka, Missouri in unincorporated St. Louis County, the Tyson Research Center serves as the biological field research campus for Washington University in St. Louis (Washington U.), an independent university located in the City of St. Louis. Located approximately 20 miles west of the university's main campus, Tyson comprises approximately 2,000 acres of mixed hardwood forest and is part of the north-easternmost edge of the Ozark Plateau Region of Southern Missouri. The terrain lies within the hilly Lower Meramec Valley Sub-Watershed, the Meramec River forming part of the property's northern boundary. The Center is surrounded by more than 6,000 acres of interconnected, forested public and quasi-public recreation lands including Lone Elk and West Tyson County Parks, Missouri Department of Conservation Forest 44 Conservation Area, Beaumont Reservation, and Castlewood State Park—all along Interstate 44 and only 25 minutes from the main university campus near downtown St. Louis. Tyson Research Center is also located within the Henry Shaw Ozark Corridor, a designated area that includes additional parks and open space including the Shaw Nature Reserve, owned by the internationally-known Missouri Botanical Garden. Because the Tyson Research Center's surroundings are suburban, rural, and natural areas, it offers a unique opportunity for environmental sustainability research and education in an increasingly human-dominated world.

The genesis of Washington U.'s Living Learning Center originated with the need for additional classroom and multipurpose space at Tyson Research

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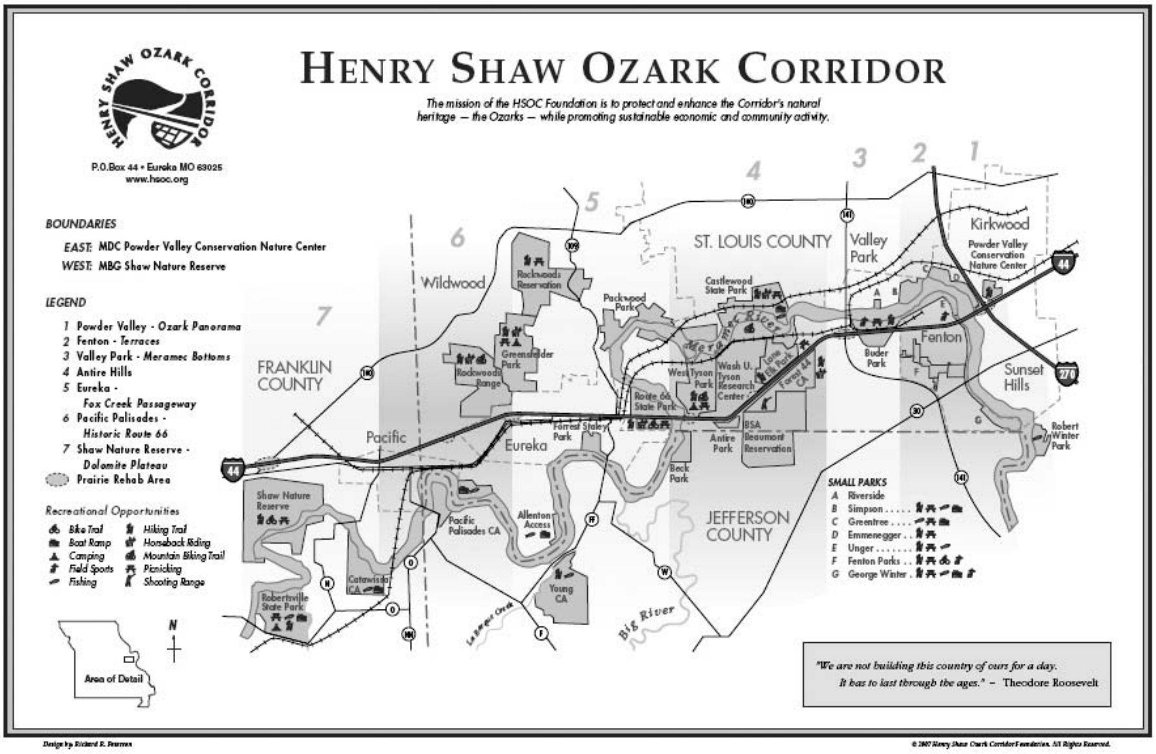
FIGURE 1. Henry Shaw Ozark Corridor.

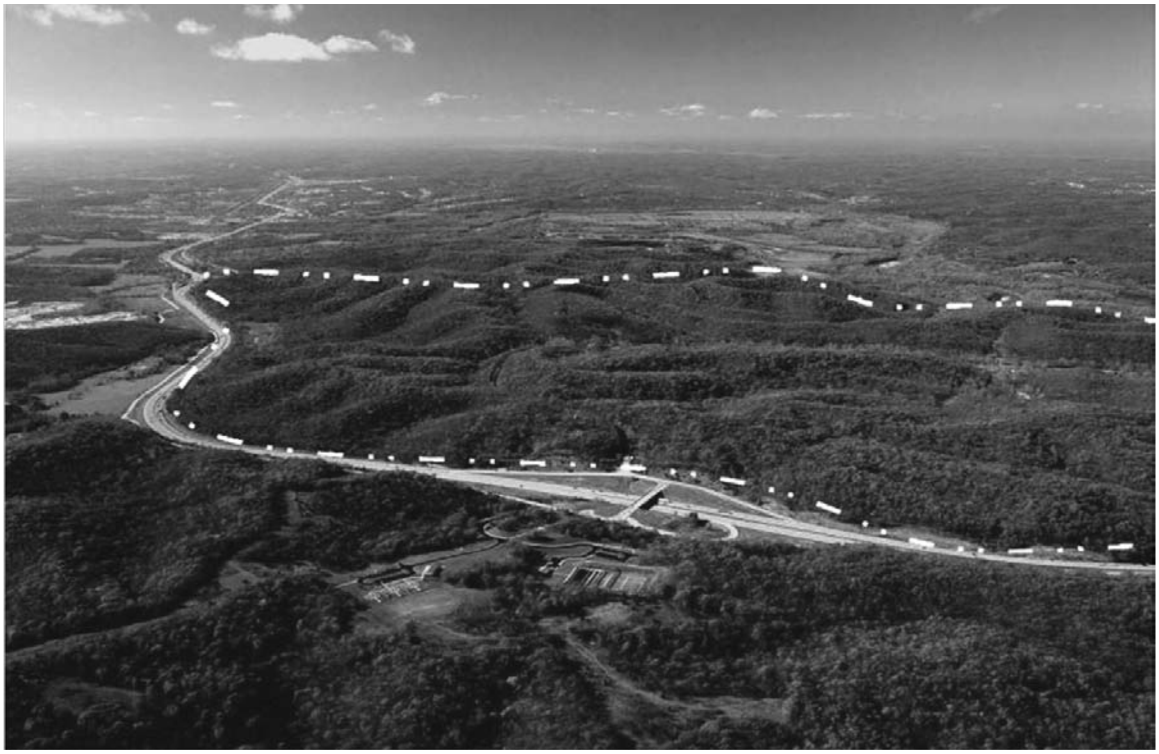


Center due to increasing use of the facility for environmental biology research, teaching, and outreach. Tyson's primary users are faculty, postdoctoral, and graduate researchers in ecology and environmental biology, and the Center hosts an active summer undergraduate research fellowship program. Additionally, Tyson has been experiencing increasing demand for flexible teaching space as more university courses and programs begin to take advantage of Tyson as a living laboratory for the natural and environmental sciences. As a result, Tyson was facing an upcoming summer field season with more research projects, more field technicians, and more scientists than ever before. Also, the recent award of a five-year National Science Foundation grant for an informal science education project meant that 18 local high school students would be joining Tyson research teams for summer internships. It was clear to administrators at Tyson and Washington University that additional space at Tyson would be necessary within a very short timeframe to meet this growing demand.

Washington U.'s facilities design standards already require newly constructed buildings to be certified LEED Silver at a minimum. Yet because this particular construction project would be situated at the university's field station, all parties agreed that something beyond LEED should and could be achieved. In particular, given that Tyson's mission as an ecological research station is fundamentally related to environmental sustainability, Dr. Jonathan Chase, director of Tyson, promoted the idea that the center's newest building should be as "green" as possible. Hellmuth + Bicknese Architects then suggested the Living Building Challenge (LBC) as a forward-thinking template for the new building at Tyson.

Likewise, the institution viewed the LBC as a logical next step in its strategic goals for campus sustainability, particularly issues related to energy, environment, and sustainability to be among the biggest challenges of the 21st century. As a premier institution of higher education whose mission is to foster excellence in teaching, research, and service for

FIGURE 2. Tyson Research Center.



the local and global community, it was inherent that Washington U. take a leadership role in identifying ways to transform these challenges into opportunities. To do so, the university's primary objectives include: to *educate* and train the next generation of sustainability leaders, scholars, and practitioners; to *research* and innovate sustainable technologies and strategies; to *operate* according to the principles of sustainability; and, to *engage* and empower partners to find and implement sustainable solutions. As such, Washington U. has been working for several years to transform its campus into a "living learning laboratory" that connects scholarship and discovery directly to design and management. By doing so through this process, the university believes it will find sustainable solutions to local and global challenges and bring rapid transformation to its campus and to society.

The Tyson Research Center and its Living Learning Center are a central part of the sustainability efforts at the university. Its interdisciplinary academic programs, including those being fostered through the NSF grant, exemplify Washington U. teaching efforts on sustainability. In addition, Tyson is part of Washington U.'s International Center for Advanced Renewable and Sustainability (I-CARES) and home to growing research in environmental sustainability. Also central to the Living Learning Center is outreach on the human connection with the environment. Therefore, it was only logical for the university to create the Living Learning Center as a facility pushing the limits of sustainable design, host and serve as a subject of its sustainability academics and research, and become a center of inspiration and outreach. With these goals, the LBC represented the best test to determine if the university and its design team had "the right stuff." Currently, it is on track to become certified as the first "living building" in the world.

Integrated Design Process

The impending start of the next field research season set an exceedingly aggressive schedule for project completion. Once the design team was given notice to proceed, they developed the building program with all project stakeholders participating. The project officially launched with a design charrette, including broad representation from Washington U. Facilities Planning & Management and Sustainability staff, a faculty member from the university's School of Architecture, Tyson staff, and the complete design team including architectural, landscape, civil, mechanical, electrical, and plumbing engineers.

During this green charrette, the architect suggested the Living Building Challenge as an alternative to LEED—not only did the standard set a very high sustainability threshold, it would also capture all aspirations of the team. It was particularly applicable due to the smaller size of the project, its location, and its programmatic function as an environmental learning center. The living systems aspect of the LBC also complemented the backgrounds of the administration and teaching staff who are predominately biologists and environmental scientists.

The integrated design process is considered essential for any type of green design, and even more critical in a project attempting to meet the Living Building Challenge. The entire design team was present at the charrette, including:

Design Team:

Architect: Daniel Hellmuth, Hellmuth + Bicknese Architects

Mechanical, Electrical, Plumbing Engineering: Matt Ford, SolutionsAEC

Landscape Architect: Anne Lewis, Lewisites

Civil Engineering and Conservation Stormwater Management: Jeff Moody, Williams Creek Consultants

Stakeholders Group: Washington University

Hank Webber, *Executive Vice Chancellor for Administration*

Art Ackerman, *Associate Vice Chancellor for Facilities Planning & Management*

Matt Malten, *Assistant Vice Chancellor for Sustainability*

Steve Rackers, *Manager of Capital Projects*

Neal Schaeffer, *Facilities Project Manager*

FIGURE 3. Design Charrette.

Jonathan Chase, *Director of Tyson Research Center*

Kevin Smith, *Associate Director of Tyson Research Center*

Andrew Johnstone, *Business Manager Biology Department*

Victoria May, *Director of Science Outreach*

Susan Flowers, *Science Outreach Program Faculty*

From the onset of conceptual design, the entire design team, as well as the broader group of building stakeholders, supported a design approach to meet the Living Building Challenge. Programmatically, the building was intended to be adaptable, multipurpose, focused on learning, and to promote and facilitate indoor as well as outdoor teaching spaces.

The Living Building Challenge

Initially, the design team recommended use of the Living Building Challenge as the preferred green site and building benchmark due to the relatively small size of the program (approximately 2,900 SF). Given the nature of the project, its educational mission and location, the science background of the Tyson faculty, and the overall sustainability mission within the university, this proved to be a catalytic decision. Not only would LBC embody all of the environmental initiatives discussed previously, the Challenge would also foster a strong connection between the building process and a biological process which, in turn, could serve as a learning tool itself. In hindsight, although the participants understood the significance of the LBC and the difficulty in realizing its goals, designers had only a vague idea of the challenges ahead.

LBC is a rigorous performance standard, created to define and measure sustainability in the built environment. Introduced by the Cascadia Region Green Building Council—and endorsed by the U.S. Green Building Council—in 2005, LBC strives to achieve performance levels beyond the points or credits prescribed by LEED® and other green building rating programs. The term "living building" was first defined in a 1999 article in *The World & I*, "The Living Building"[1] by architects Bob Berkebile and Jason McLennan.

Recently, the Cascadia Region Green Building Council formed the International Living Building Institute (ILBI), a non-governmental organization to administer and continue development of this breakthrough initiative. The Institute's current LBC Version, 1.3, outlines a series of standards requiring buildings to achieve zero net energy, zero net waste, and zero net water levels. To earn the LBC rating, each project must meet 16 prerequisites organized within six performance areas, or "Petals": Site, Energy, Materials, Water, Indoor Quality, and Beauty & Inspiration. More specifically, these address the following sustainable design elements:

- **Site:** Responsible Site Selection; Limits to Growth; Habitat Exchange
- **Energy:** Net Zero Energy
- **Materials:** Materials Red List (project must not include any materials containing known, persistent bio-accumulative toxins [PBTs], carcinogens, and reproductive toxicants); Construction Carbon Footprint; Responsible Industry; Appropriate Materials/Services Radius; Leadership in Construction Waste
- **Water:** Net Zero Water; Sustainable Water Discharge
- **Indoor Quality:** A Civilized Environment; Healthy Air: Source Control; Healthy Air: Ventilation
- **Beauty & Inspiration:** Beauty and Spirit (project must contain design features intended solely for human delight and the celebration of culture, spirit, and place appropriate to the function of the building); Inspiration and Education

In addition, two rules govern the standard[2]:

- All elements of the Living Building Challenge are mandatory. Many of the requirements have temporary exceptions to acknowledge current market limitations. These are listed in the footnotes of each section. Exceptions will be modified or removed as the market changes.
- Living Building designation is based on actual, rather than modeled or anticipated, performance. Therefore, buildings must be operational for at least twelve consecutive months prior to evaluation."

Design, Code, and Construction Challenges

Following the project launch, designers encountered numerous challenges, including building code issues with St. Louis County and ongoing cost issues related to meeting Challenge requirements—particularly Net Zero Energy and Water components, as well as materials and distance restrictions. Collectively, Washington U. Facilities staff, Tyson representatives, and the design team chose to meet with St. Louis County Public Works before submitting drawings to the county to fully convey the project's goals and objectives. Design strategies were then summarized in a conceptual design report resulting from the charrette. In broad terms, the design team received full support from the county; however, as conceptual design diagrams were submitted for various systems, the group hit several roadblocks and convened another meeting. Ultimately, the county agreed to review the building using the "Alternate Compliance" method. Rather than examining systems, as proposed, that did not meet code, the review was based on their outcome, which put the burden of proof on the design team. As a result, despite rigorous review, all systems were ultimately approved including the rainwater-potable water design, which has proved a barrier in many other LBC projects.

In addition, construction budget challenges were amplified by the relatively small size of the building, the combination of systems proposed, and the significant cost of implementing a net zero energy photovoltaic building. Restrictions and requirements of the LBC also had a significant cost impact. Despite broad support from the university (including the dean of the School of Arts and Sciences, Dr. Ralph

Quatrano, Neal Schaeffer, the facilities project manager, and Dr. Jonathan Chase and Dr. Kevin Smith, Tyson's director and associate director respectively, Andrew Johnstone, business manager for the Biology Department, and Hank Webber, executive vice chancellor for Administration), the project underwent a severe value engineering process to reduce costs. Still, designers were able to maintain the core features necessary to meet the building's programmatic requirements while achieving the LBC goals, along with provisions for adding design features back at a later date. One example is that a part of the center's roof area was structured to support a green roof; however, the green roof blocks were removed from the project scope. This was an easy target since the conservation stormwater design was already meeting the requirements of 100 percent infiltration, as required by the LBC.

Due to the project's aggressive schedule, the design team was given only two months to complete construction drawings, as the building had to be complete by May 2009 to meet the needs of Tyson's upcoming summer program. The real challenge came during construction, when each shop drawing had to go through a vetting process for compliance with LBC requirements, which created a defacto Design-Build delivery method. This, in turn, required unprecedented flexibility from the owner, the university, the awarded contractor, Justin Bingman of Bingman Construction, users of the building at Tyson, and the entire design team. All parties were aware that project schedule and budget pressures could at any time have spiraled out of control. As the project unfolded and reached, essentially, a crisis equilibrium, this facilitated a more creative process of problem solving and rapid discovery of solutions during construction thanks to steady input from all parties.

As noted earlier, the design team and stakeholders collectively addressed a number of green strategies to achieve the building's goals of zero net energy, zero net waste, and zero net water levels in meeting the 16 prerequisites of the LBC.

ELIMINATING THE CONCEPT OF WASTE

Waste water, human waste, stormwater runoff: each term implies a lack of utility and value and the need for waste removal. Within the built environment, designers have long been ingenious at inventing and perfecting devices and systems to remove waste and make disposal virtually invisible. The Toto® toilet is perhaps the apex of this technology; despite an innovative seat warming design and audio properties, not to mention multi-functional sprays, it is still essentially a waste relocation device. In fact, these devices usually compound the waste problem, making it even more difficult to address. Therefore this relocation device also has a down-cycling effect.

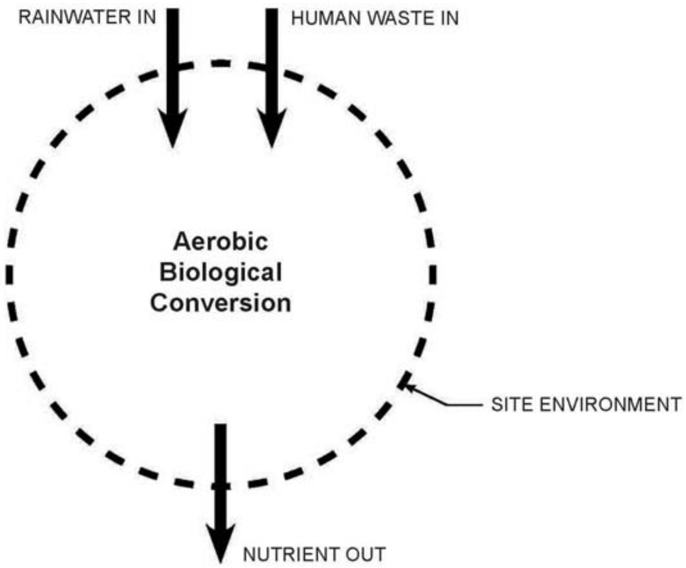


FIGURE 4. Nutrient Conversion—Natural System.

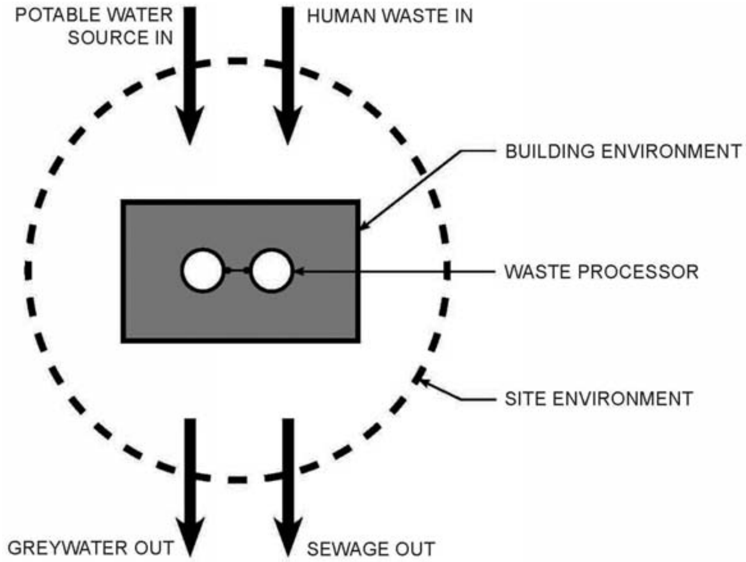


FIGURE 5. Waste Creation + Relocation—Conventional Building.

Although not expressly stated, Net Zero Waste might be a good prerequisite to add to the Living Building Challenge. It is already implicit for several LBC requirements. Integral to explaining the systems within the Living Learning Center, it becomes difficult, if not impossible, to use the word *waste*, as the systems themselves are serving an entirely different purpose. Waste suddenly becomes a feedstock or nutrient that—rather than being down-cycled—is up-cycled into a manageable asset. Systems become nutrient conversion rather than relocation devices and use natural processes or passive technology to achieve this state.

While these concepts sound good in theory, the LLC design team wondered whether net zero waste could be accomplished in a commercial or educational building, meet current building codes, and remain affordable and reasonable to manage.

In the case of the Living Learning Center, the human nutrient conversion is accomplished with a composting toilet—in this particular case, a Clivus Multrum M12 Unit.

This relatively simple but sophisticated system transforms both urine and feces through the activity of a range of organisms, including bacteria, fungi, and small invertebrates—the same organisms found in healthy, fertile soil. Indeed, a soil-like ecology best describes the compost toilet. More specifically, the process—aerobic decomposition—is made possible by an absence of water for flushing and by gravity separation of urine and feces. At the start, a thick bed of pine shavings is added to the compost chamber to encourage proliferation of desirable organisms and help create a porous texture. With the first use of the system, bacteria from feces begin establishing a broad spectrum of decomposers, most of which find their way into the composter through its several openings. The porous texture of the composting mass and the sloping floor of the device ensure relatively rapid passage of urine to the lowest level. During the several hours it takes for urine to make its way to the bottom of the system, nitrifying bacteria (e.g., nitrobacter and nitrosomonas) convert urea and ammonia into nitrite and nitrate. Nitrate is a form of nitrogen readily taken up by plants and is among many substances necessary for healthy plant growth. It is a primary ingredient in chemical fertilizer, which is a fossil-fuel-based commodity. The result is a chemically stable and biologically safe, nearly odorless liquid fertilizer, rich in micro- and macro-nutrients. This fertilizer, which is automatically pumped from the compost unit into a nearby 500-gallon storage tank for later use in the organic garden and for landscape fertilizing, is the primary end-product of the process. For every 20 uses, approximately one gallon of fertilizer is produced.

FIGURE 6. Nutrient Conversion—Living Building.

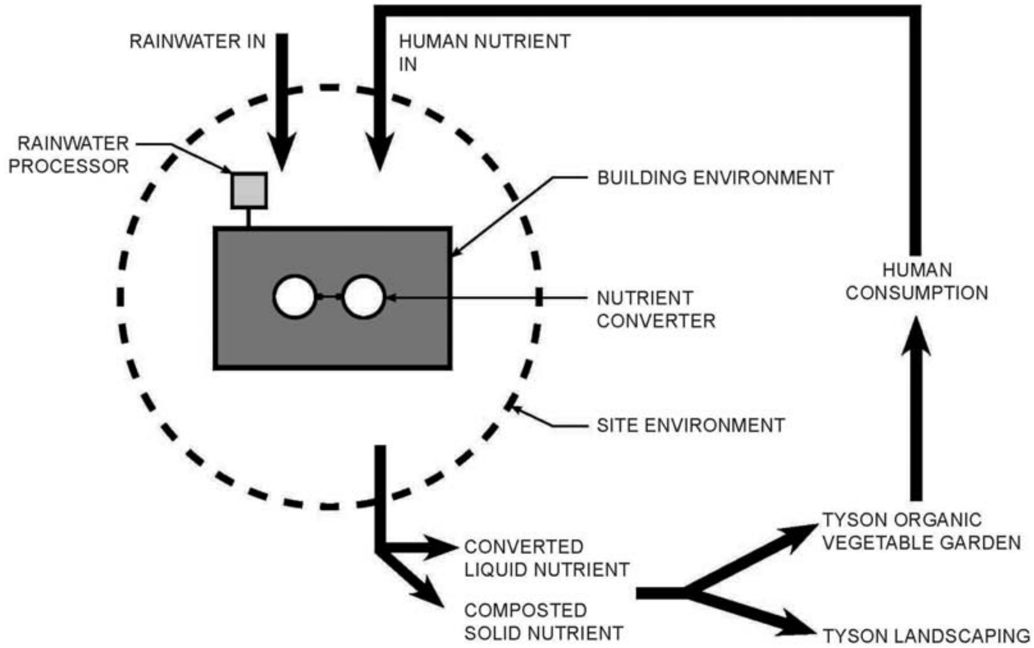
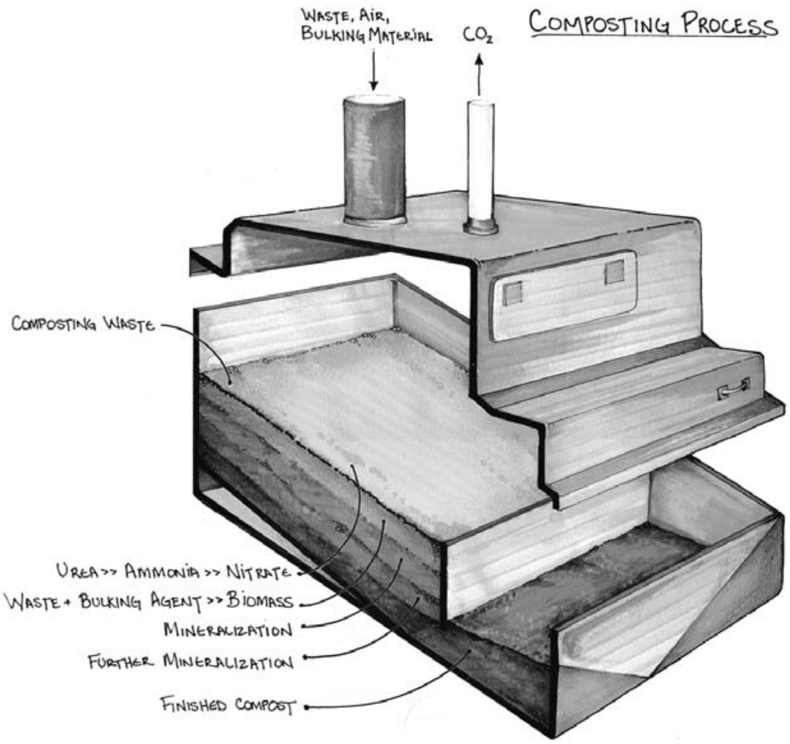


FIGURE 7. Nutrient Conversion—Composting (courtesy of Clivus Multrum).



Meanwhile, feces remain in the relatively dry condition of the compost unit, subject to the action of another set of soil organisms, including "compost" or "red" worms (*Eisenia foetdia*), the only organism manually added. Over the course of several years, feces are reduced in volume by over 90 percent. Potential pathogens are destroyed by competing organisms or simply die off over time. The result is a humus-like material, rich in nutrients and organic matter, with a chemical, biological, and aesthetic character comparable to topsoil. This compost has value as a soil conditioner as well as a fertilizer. Once the system is full after several years, only the oldest material is removed from the bottom (less than 30 percent of total contents); thus, the process is never completely interrupted. A small spray device adds approximately a gallon of water daily, to ensure best conditions for decomposition. Primarily vent gases include carbon dioxide and water vapor.

The compost toilet fixture is, in essence, a 14-inch tube configured in an absolute vertical connection to the composting unit. No water is used for flushing. A small, continuously-running fan pulls air down the fixture, creating a completely odorless restroom. In addition to its nutrient recycling benefits, the compost toilet saves all water that would otherwise be used for flushing: in this case, up to nearly 50,000 gallons annually. Perhaps more important, nutrients otherwise flowing into a conventional septic system and contributing to water pollution now remain on site and become recycled for plant growth.

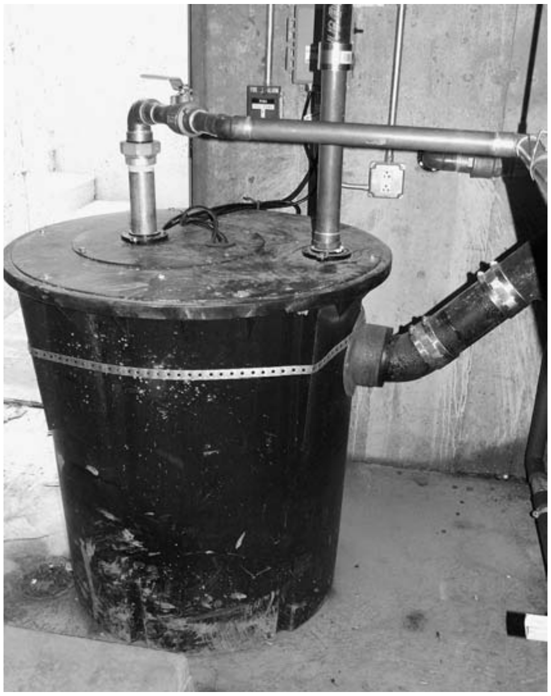
FIGURE 8. Compost Toilet—Chutes, Exhaust.

Architecturally, the toilet room features operable windows, plenty of natural light, and even a solar tubular skylight. For some users, there is still an intimidation factor, which could perhaps be minimized with some of Toto's white noise technology!

FIGURE 9. Compost Toilet—Misting System.

FIGURE 10. Nutrient Staging—Nutrients.

FIGURE 11. Nutrient Staging—Greywater Dosing Basin.



The system does require some maintenance—a task perhaps more culturally than technically challenging. Nutrient cones must be turned monthly, wood chips added periodically, and ongoing attention to detail given to a living biological conversion system.

The other biological process necessary to the building's nutrient recycling is its Greywater Irrigation System. Elegant and simple, the system collects water from all building sinks into a dosing basin. Greywater is stored in the basin for about a day, or until an appropriate volume has been reached, which then creates a flooding dose (approximately 35 gallons) in the irrigation chambers. An effluent pump sends greywater to the irrigation chambers. This project's three 18-foot irrigation chambers (made of 12-inch polyethylene) are set within the plant root zone (no more than 12 inches below grade) in a designated area of sufficient soil porosity to ensure that conditions within the chambers remain biologically aerobic even with the daily input of greywater. High-level placement of the chambers allows plants to use the small amount of nutrients in greywater and for stabilization as the water passes downward,

FIGURE 12. Graywater Treatment Plan (Solutions AEC W/Clivus Multrum).

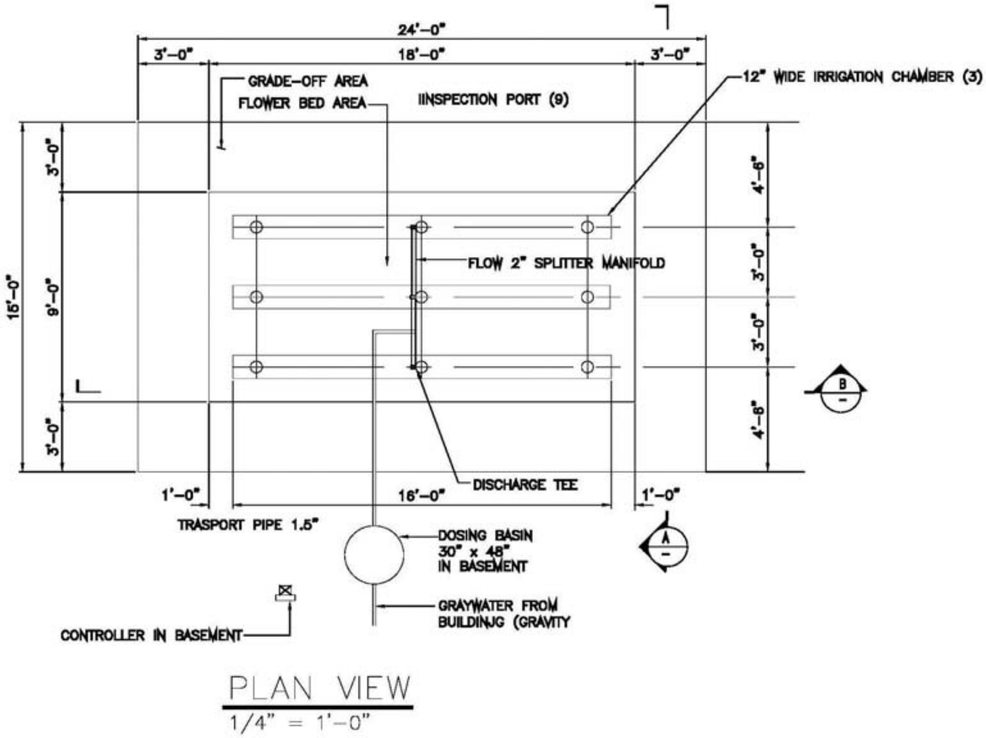


FIGURE 13. Graywater Garden.

helping—along with rainwater that has fallen onto the building—to recharge groundwater. The large interface between water and soil areas allows the system to operate without filtration. There is no regular maintenance.

Interconnected Biological Cycles: Net Zero Water and Stormwater Management

Another characteristic of a living building: mitigating the effects of construction on the natural hydrograph of a site. In this case, the existing project site was already degraded, covered in large part by a deteriorated asphalt parking lot and miscellaneous abandoned building pads. No existing buildings were removed as part of the project. (Note the aerial photo is out of date.)

Site development for the Living Learning Center at Tyson was challenging due to parking requirements set forth by St. Louis County. As part of the design process, designers agreed to remove the existing parking lot, with the loss of approximately 12 parking spaces. Simultaneously, Tyson staff expressed interest in creating an interpretive area between an existing building and the new building by eliminating any paving or driveways where possible. The design team, working with the county's staff, developed a strategy where existing parking for an adjacent building could be combined with parking for the Living Building. As a result, only four new ADA spaces were required, with an additional space for van access, dramatically improving the interrelationship between the existing administration building and the new learning center.

Additional constraints at the site included an adjacent stream with a 100-year floodplain and existing mature healthy trees. The Center's building footprint was moved in mid design to protect a heritage Chinquapin Oak, requiring recalibration of the natural stormwater design to minimize impact within the expansive drip line of the tree and reduce shading on the PV panels. Non-native trees were

FIGURE 14. Existing Site Conditions.

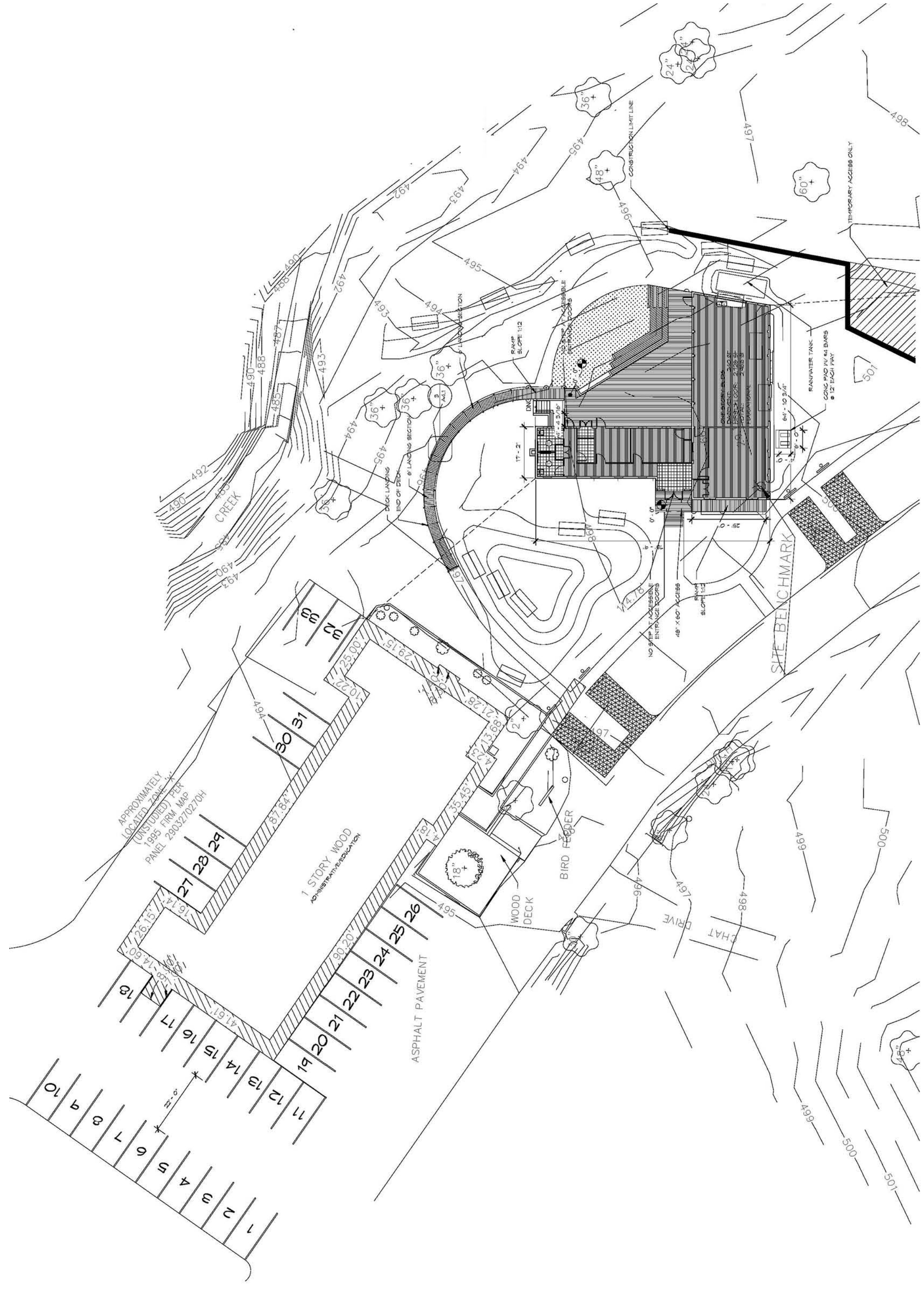


FIGURE 15. Site Restoration with New Building.

removed and utilized according to the *Construction and Demolition Waste Plan*.

Finally, stormwater management for the Living Building emphasized Low Impact Development (LID) techniques to reduce the volume and rate run-off of the new construction. The goal of LID is to treat stormwater as close as possible to an area where the rain falls. Designers modified the proposed LID methods to accommodate soil types on site. Specific stormwater management strategies included rain barrels, rain gardens, porous concrete, and rainwater harvest tanks.

Stormwater for the Center's south roof is diverted into a 3,000-gallon subsurface rainwater harvest tank. First, roof water is collected via an initial bypass through a first-flow diverter. This diverter is designed to limit the amount of solids and debris passing into the tank and filtered within the building. Water from the tank is filtered and irradiated, then used for potable water within the building. If water usage is low, stormwater is discharged into a swale and returned to the adjacent stream. Periodic system cleaning is also necessary to eliminate any solids and other materials which have bypassed the first flush diverter.

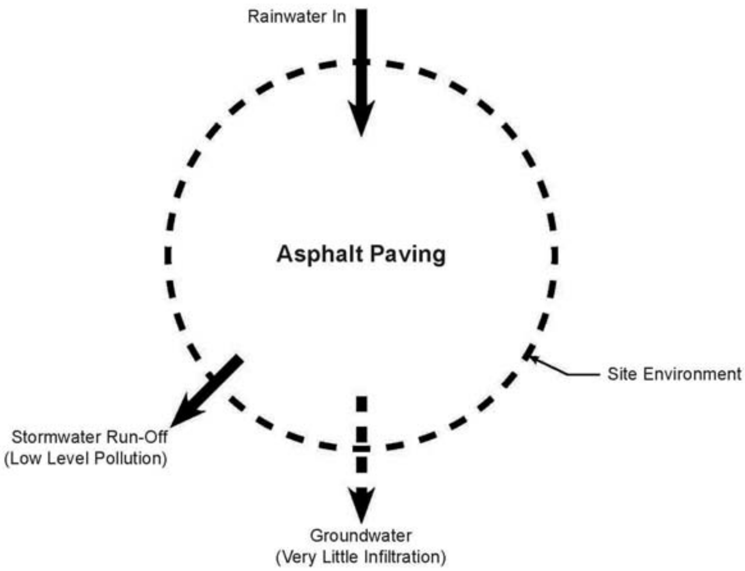


FIGURE 16. Water Pollution—Existing Conditions.

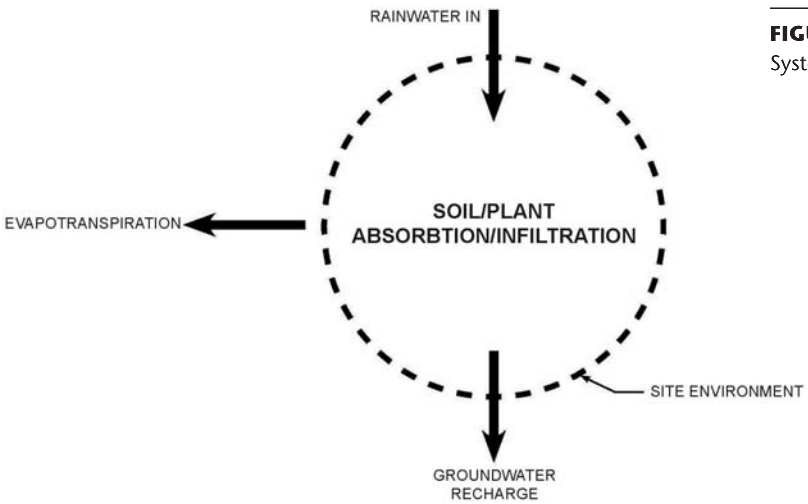


FIGURE 17. Water Recharge—Natural System.

FIGURE 18. Water Treatment—Conventional Building.

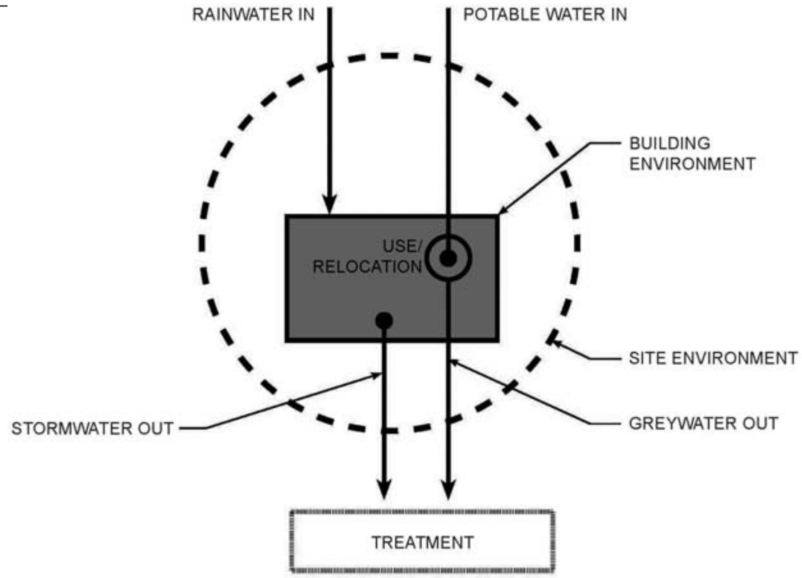
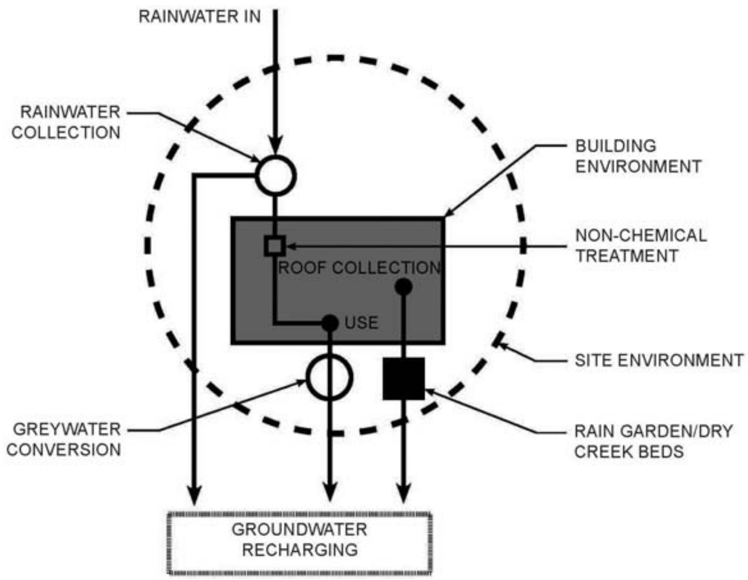
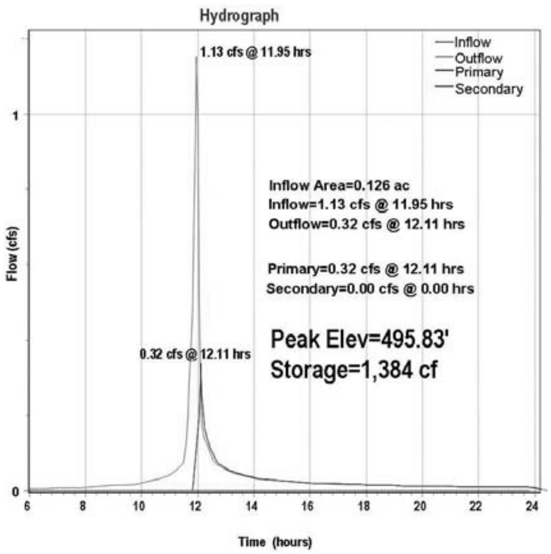


FIGURE 19. Water Recharge—Living Building.



Additionally, stormwater for the north roof is collected within a rain barrel, designed to slow water for use in landscape watering. Overflow from the rain barrel enters a swale and discharges into the constructed rain garden. Porous concrete, utilized for the ADA parking spaces, allows stormwater to infiltrate to base media rather than flow into a receiving stream with no treatment. Stormwater that does not infiltrate soils is carried to the rain garden via an underdrain. All stormwater for the northern portion of the site enters the rain garden for final reduction of volume and discharge rates. The north roof was also designed to accommodate a green, planted roof, thereby realizing further stormwater treatment upon its installation at a later date.

FIGURE 20. Site Hydrograph (Williams Creek).



NET ZERO ENERGY

Accomplishing a Net Zero Energy building in accordance with the Living Building Challenge called for a true *whole building approach*. Primarily, this included a comprehensive reduction in demand while simultaneously generating sufficient, on-site energy.

The design team's primary goal involved creating a building (and site) that resulted in a comfortable, usable space with as little energy as possible. Through multiple design charrettes, participants outlined and agreed upon the following energy reduction strategies:

- Proper building orientation
- High efficiency glass
- Shading of exterior glazing
- R-30 roofing systems
- R-30 wall systems
- Point-of-use domestic water heating
- Utilization of natural ventilation

FIGURE 21. Conservation Stormwater Design (Willams Creek).

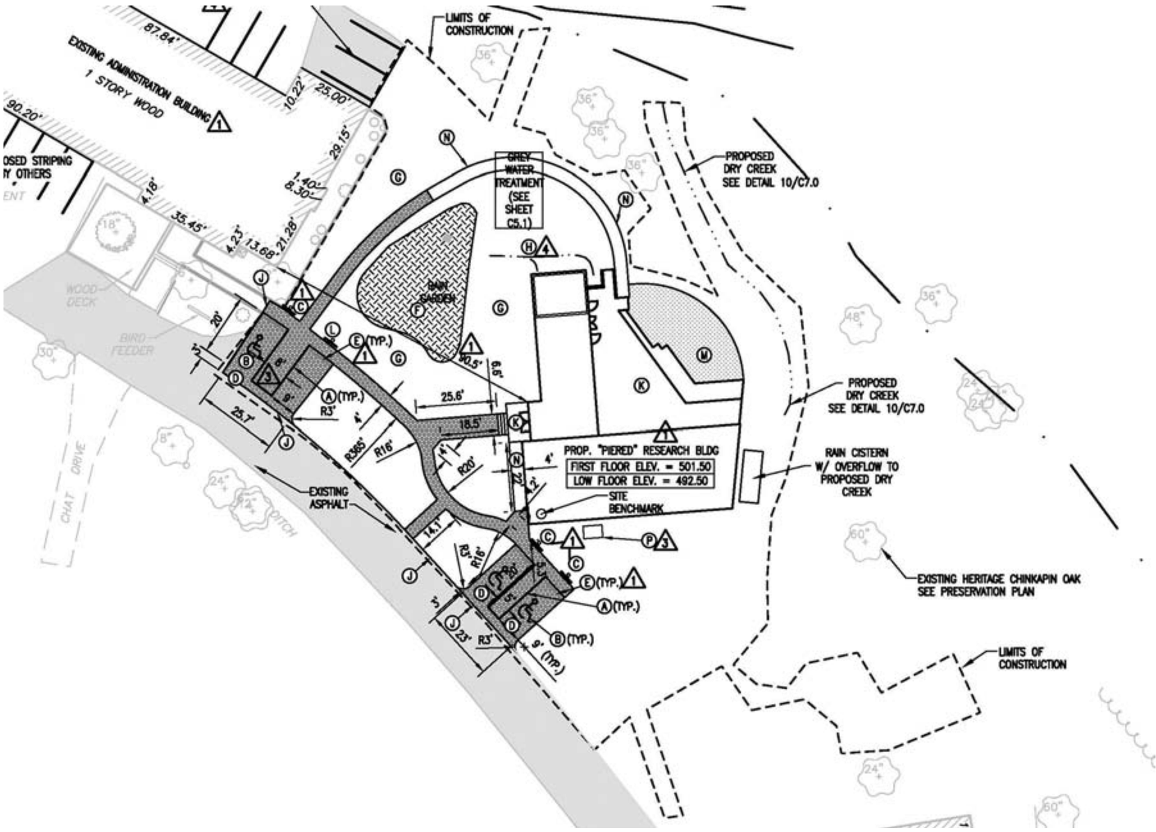


FIGURE 22. Potable Water System Diagram (Solutions AEC).

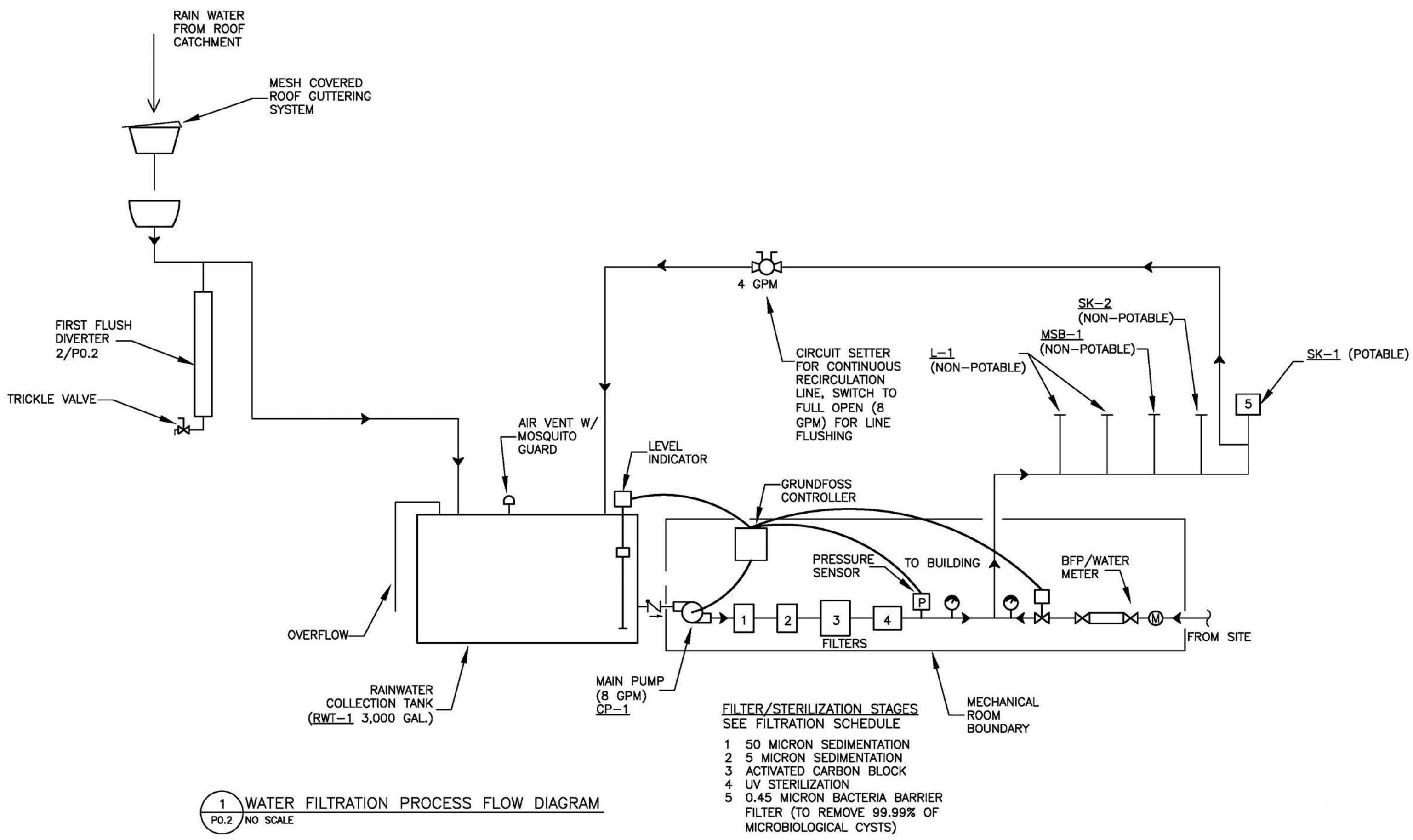
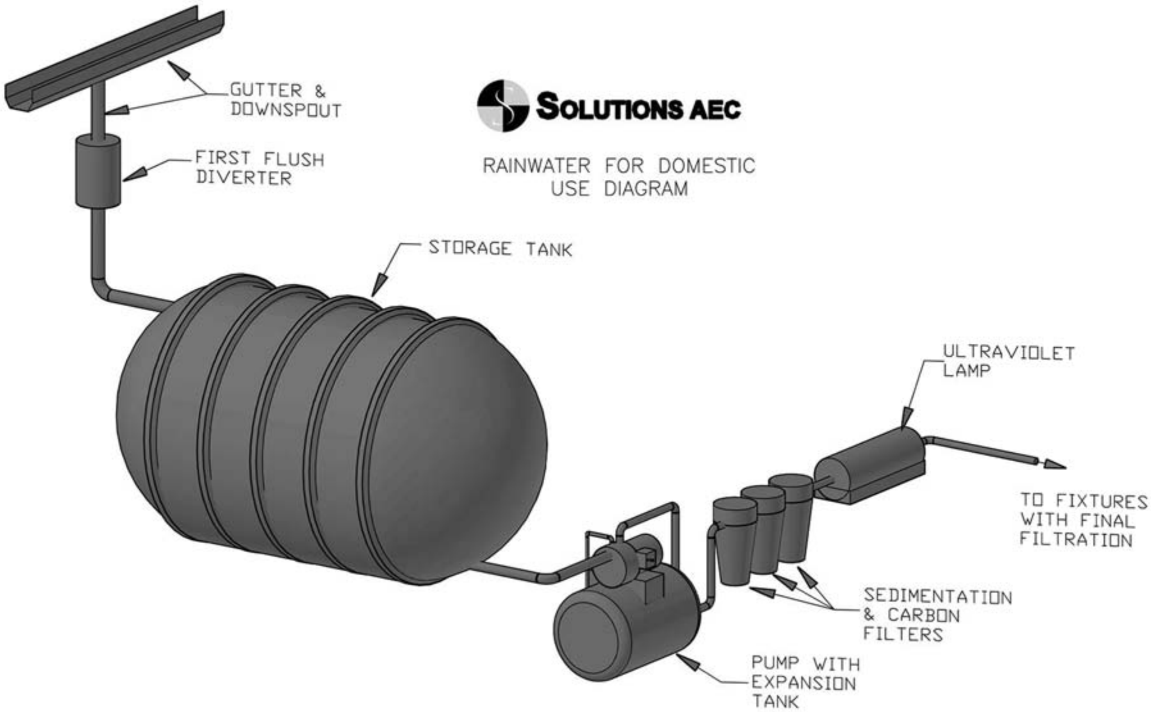


FIGURE 23. Potable Water System Drawing.



- High efficiency HVAC systems
- Demand control ventilation
- Daylighting of occupied spaces
- Lighting controls
- Energy Star appliances and equipment
- Owner training on efficient operation of the building

As noted here, the building successfully incorporates several traditional and non-traditional methods of energy reduction. A natural ventilation system, in conjunction with proper owner training to ensure systems are not conditioning the outside, provides significant energy savings during mild climate conditions. When mechanical ventilation is required, a variable volume dedicated energy recovery unit minimizes energy consumption along with CO_2 sensors in key learning areas.

On-Site Renewable Energy Production

The Living Learning Center's primary energy source is a 17.2 kW photovoltaic array, positioned on the south-facing roof of the building. This array produces most of the energy consumed by the building's HVAC systems on an average day. The utility company supplies energy for building needs when solar radiation is inadequate. Over the course of a year, electrical energy production is projected to exceed energy consumption.

FIGURE 24. Natural System.

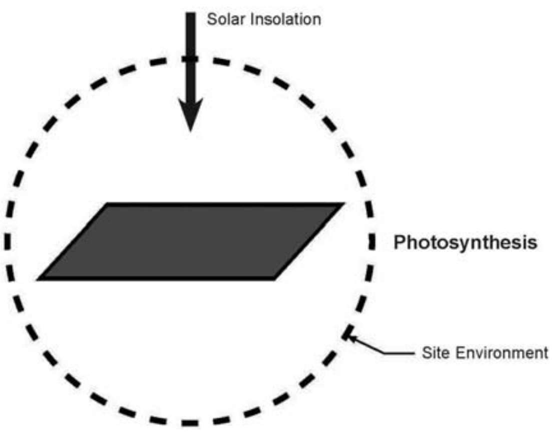


FIGURE 25. Conventional System.

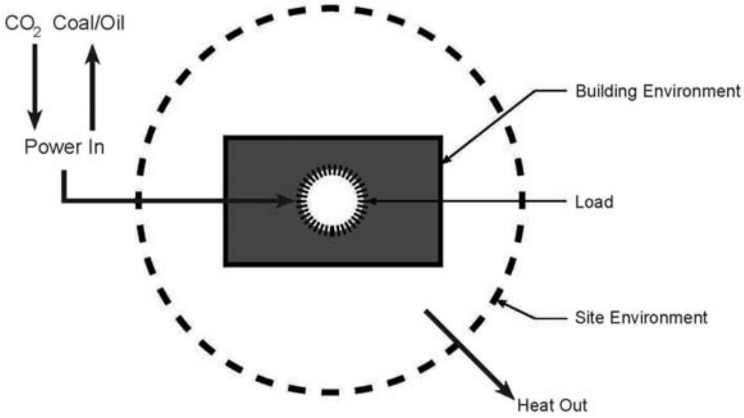
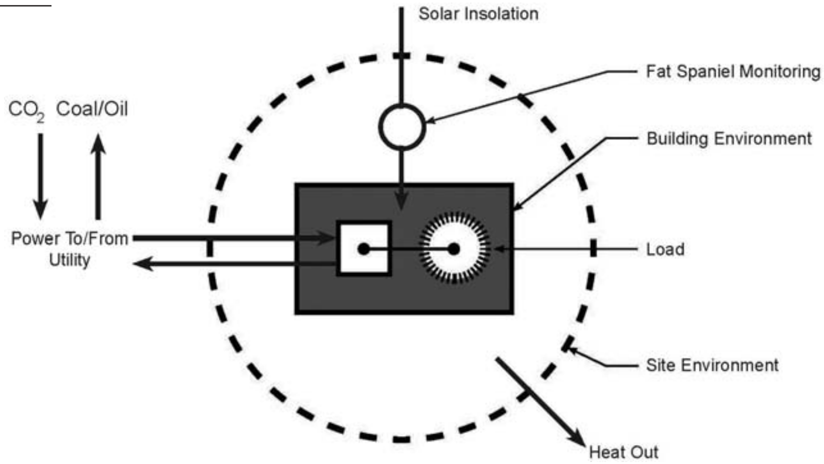


FIGURE 26. Living Building.



Components of the PV array include:

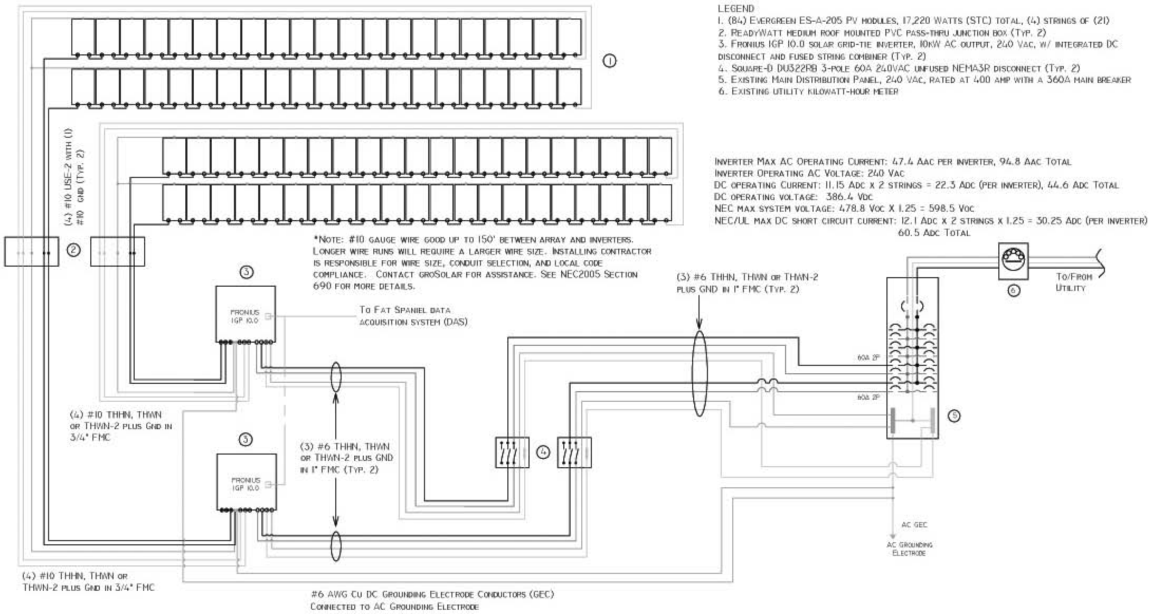
1. (84) Evergreen ES-A 205 watt solar modules (panels)
2. (2) Fronius IG Plus 10.0-1 Inverters
3. S5! PV Kit (penetration free attachment system for standing-seam metal roof)
4. Fat Spaniel Web-based monitoring system

The Living Learning Center's 17.2 kW system photovoltaic system was integrated into the design and goals of the building and the Living Building Challenge. Factors taken into account when designing the system included: building layout and orientation, surrounding shading, energy modeling estimates, and budget. The relatively small footprint of the building and the teaching focus of the Living Learning Center provide a "best case" scenario to demonstrate solar applications in the Midwest. Furthermore, the combined vision of the university and the design team created an opportunity to develop the Center as an organic system that generates its own energy on a daily basis.

This photovoltaic grid-connected system relies on the electric utility as storage during much of the day (the meter spins backward) and then pulls energy back from the utility at times when building usage is greater than solar production—for example, to power base loads at night or during cloudy days.

To maximize solar production, the building is oriented nearly directly south. Furthermore, during the design process, the team shifted the building location to the west to decrease shading from nearby

FIGURE 27. 3-Line Diagram of Photovoltaic System—Dane Glueck, Missouri Solar Living.



indigenous trees. The layout of panels on the roof left an open area in the lower eastern corner that received morning shade. This design limited shading of the array and also allowed for additional panels in that location if required to meet the building's energy demands. Ultimately, the system design was meant to integrate organically into the building structure and surrounding environment.

System components included 84 205-watt solar modules wired to two 10-kilowatt inverters located in the electric room of the building (see pictures). The inverter converts the solar-produced DC electricity to AC electricity, which is fed back into the main electric panel via breakers. Disconnects are placed between the inverter and the electric panel and positioned on the exterior of the building near the meter. The system features a Web-based monitoring system, designed to educate students and provide valuable feedback on solar production on an hourly basis (see image). Finally, the standing-seam roof works well with the non-penetrating, clip mounting system that provides sturdy fixation of the panels without penetrating the roof (see image).

FIGURE 28. PV Panel Installation.

NET ZERO CARBON AND WILDLIFE HABITAT EXCHANGE

To account for carbon emissions related to the building construction, the LBC requires the carbon impact of construction to be calculated using and then mitigated through use of a one-time carbon offset.

FIGURE 29. PV Panels on Roof (photo courtesy of Joe Angeles, Washington U.).

FIGURE 30. Carbon Load—Conventional Building.

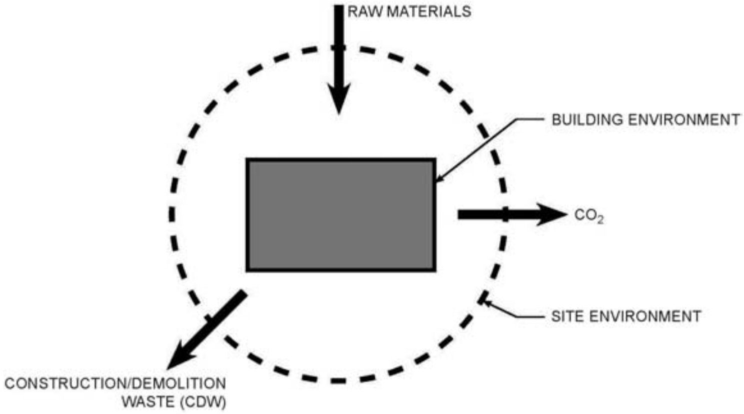


FIGURE 31. Carbon Load—Living Building.

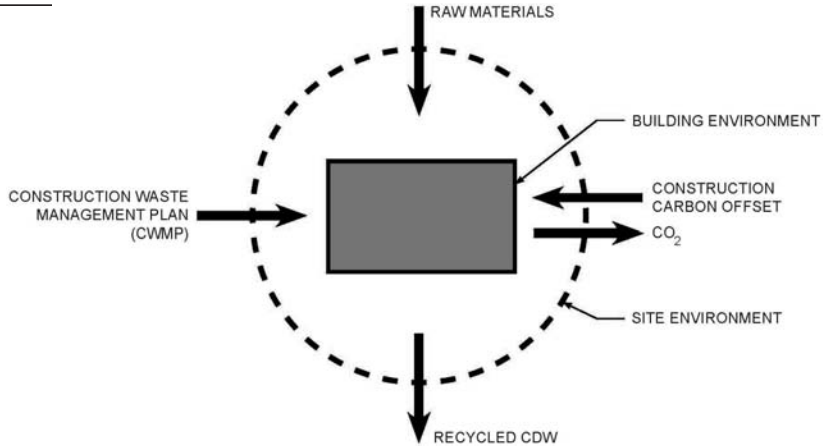


FIGURE 32. Habitat Degradation: Conventional Building.

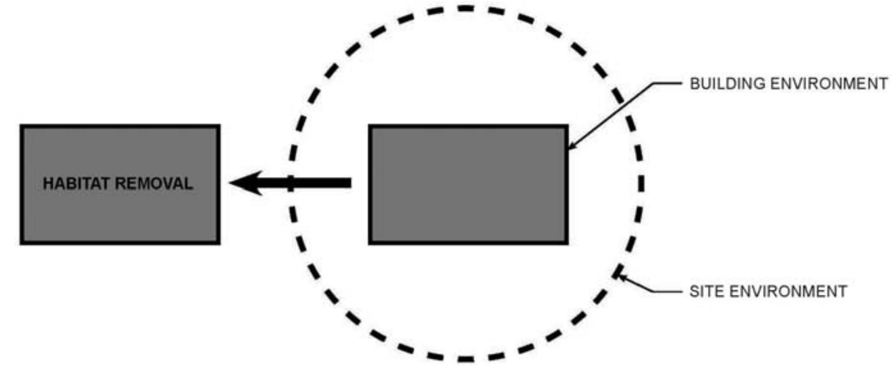
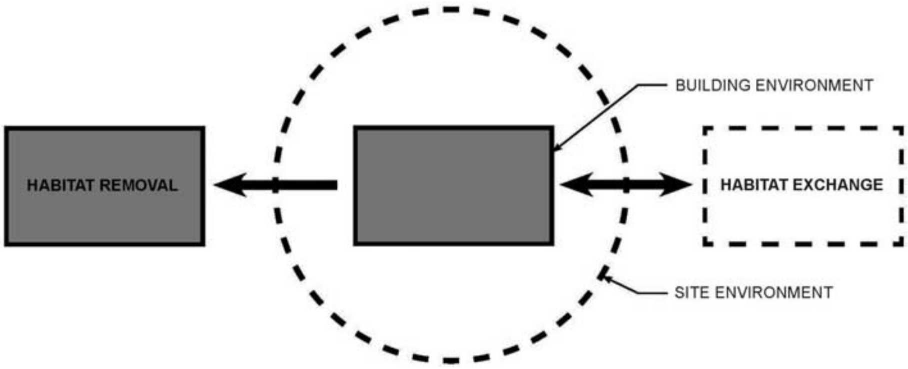


FIGURE 33. Habitat Exchange—Living Building.



The offsets must be purchased through a provider that meets or exceeds the Gold Standard.[3]

Another effect of site development and construction is the potential loss of wildlife habitat. Given that the existing site for the building was a degraded parking lot, the Center's development actually improved the local habitat substantially with the introduction of a rain garden and landscaped area that had been an impervious surface with runoff into a nearby ephemeral stream. A series of bat houses (along with two bat cams) were also integrated into the west façade of the center, just under an overhanging eve so that the building itself can become habitat.

Through The Nature Conservancy's Conservation Buyer Fund, a local opportunity in the Ozarks was identified for helping with land preservation and working with landowners by teaching them about sustainability. This was a preferable alternative for Tyson to the Adopt an Acre Program and will help TNC preserve land and waterways in the Ozarks while also meeting the Habitat Exchange requirement.

MATERIALS, DISTANCE, RED LIST, AND REGIONALISM

One aspect of building design often missing in modern architecture is a sense of context and regional identity. The practice of green architecture has begun to reestablish the importance of regionalism, just as design responds to climate, location, and context. Sustainable design should reflect its location while sustainability transitions to a living architecture. As a constructed biological system, a living building should be free of toxic materials—those which do not break down after their useful life and cause environmental degradation and human harm in their extraction and manufacturing.

For the LLC project, the team could not locate finish wood for the project that met both the Challenge's 100 percent FSC requirement as well as the distance requirement for timber extraction. They were fortunate, however, that Tyson Research Center was conducting a research project on the property to restore a section of forest to its pre-development mix of species. Invasive native species scheduled for removal in this particular forest system included Eastern Red Cedar (*Juniperus virginiana*)—no relation to Western Red Cedar (*Thuja plicata*)—and Hard Maple (*Acer saccharum*). After marking the trees with the resident forester, Travis Mohrman, and Associate Director Kevin Smith, contractor Scott Wunder was able to cut, skid, saw, and mill the entire finish wood for the project and later install the flooring himself. After milling, there was still a shortage of lumber, so the team had to consider other options. A large amount of deadfall in the area due to violent storms several months earlier made it possible to add hickory, walnut, white ash, white oak, and red oak to the building's design palette. This afforded another opportunity to match wood to best use and creatively feature different species in different areas of the building.

FIGURE 34. Tree Selection.

FIGURE 35. Freshly Cut Red Cedar.

FIGURE 36. Milling Red Cedar (Courtesy of Scott Wunder).

FIGURE 37. Finish Product in Place.

SITE AND BUILDING AS EDUCATIONAL TOOLS

Another critical aspect of a living building is to serve as a role model for other buildings, to excite and inspire similar ventures, and to promote this concept either directly through tours, as part of a specific curriculum, or passively by providing a venue for general environmental studies. As a biological field station, Tyson Research Center represents a 2,000-acre living laboratory and classroom. Therefore, the new Living Learning Center offers a home base for all the various activities that take place at Tyson as well as future initiatives, courses, and programs. The building has received a remarkable amount of attention and use since its opening on May 29, 2009.

University classes taking advantage of the new teaching spaces include the following:

- Biology 4193: Experimental Ecology Laboratory
- Environmental Studies 393: Practical Skills in Environmental Biology Research
- Earth and Planetary Sciences 210: Earth and the Environment
- Earth and Planetary Sciences 454: Exploration and Environmental Geophysics
- Design and Visual Arts 317/417: Digital Imaging and Photography
- University College–Biology 2351: Plants of Missouri
- University College–Biology 524: Ecology and Environmental Sciences

Even before completion of the building, the project produced several educational benefits. Kevin Smith contributed to a capstone seminar for the university's Environmental Studies Program, in which one group of students created a fact sheet on the building for Washington U. staff and students visiting the field station for the first time. Students in the seminar outlined details of the building and LBC requirements; their final product has become an indispensable part of Tyson's use of the Living Learning Center as an operational piece of education at the research station.

Immediately after its Friday evening opening on May 29, the Center was flooded with new users on June 1. Tyson's busy summer undergraduate research season was already well underway, and the new NSF-funded high school fellowship program was set to begin. Another early major event to be held at the LLC was the weekly Tyson Summer Seminar, a research series designed as a casual forum for local and national researchers to speak to the scientific community of Tyson Research Center, Washington U., and surrounding institutions and to foster camaraderie and collaboration. Seminars are followed by an evening barbecue social featuring locally-grown food and vegetables from the Tyson Vegetable Garden, wine from a local vineyard, and beer generously provided by St. Louis's Schlafly Brewery. All summer 2009 seminars were held at the Living Learning Center, exposing a broad variety of people to the concept and practice of a living building

As planned, the Center also served as the base of operations for teenage participants of the NSF-funded Tyson Environmental Research Fellowships (TERF) program. This program immerses teenagers in research teams at the field station, creating cultural apprenticeships in authentic scientific inquiry. The program is part of a larger joint venture between Shaw Nature Reserve and Tyson Research Center and is directed by Susan Flowers of Washington University's Science Outreach office. All participants are 11th and 12th graders from urban, suburban, and rural communities in the St. Louis area. Since the TERF program's intended impact is to increase interest in and pursuit of environmental studies, immersing students in an LBC-registered building offers a significant benefit as part of the program curriculum.

National education efforts are being focused currently on improved science, technology, engineering, and mathematics (STEM) curricula at the K–12 level; therefore the Living Learning Center serves as a very specific teaching tool. The building's alternative energy and sustainable systems have been presented to 6th, 7th and 8th graders from the Bernard Harris Summer Science Camp, 4th through 10th graders in the Alberti Program at the Washington University School of Architecture, and 5th to 8th graders in the Earthways Center's Young Green Builders camp. Middle and high school students from the Clayton School District, as well as students and teachers from a high school in India, also visited the building as part of a two-day symposium on global sustainability. District officials are viewing the building as a model for an addition to their

FIGURE 38. Earthways Center's Young Green Builders Camp.

FIGURE 39. Alberti Program.

middle school building complex. Additionally, the modular indoor and outdoor teaching spaces hosted a one-week graduate level ecology course for teachers from across the nation in the NSF Life Sciences for a Global Community institute, sparking interest in sustainable design that may spread to K–12 education communities in other cities and states.

Aside from these scheduled events, Tyson staff has been overwhelmed with interest from individuals and organizations outside the Washington U. community. Representatives of local secondary schools as well as universities, businesses, and nature reserves have visited the LLC to learn about the outcome of an LBC design process. Dozens of architects have also visited the building to study the amazing variety of sustainable technologies integrated within a single building. To accommodate this immense interest, Tyson staff has established monthly open houses to provide the local community with an opportunity to experience and learn from the LLC.

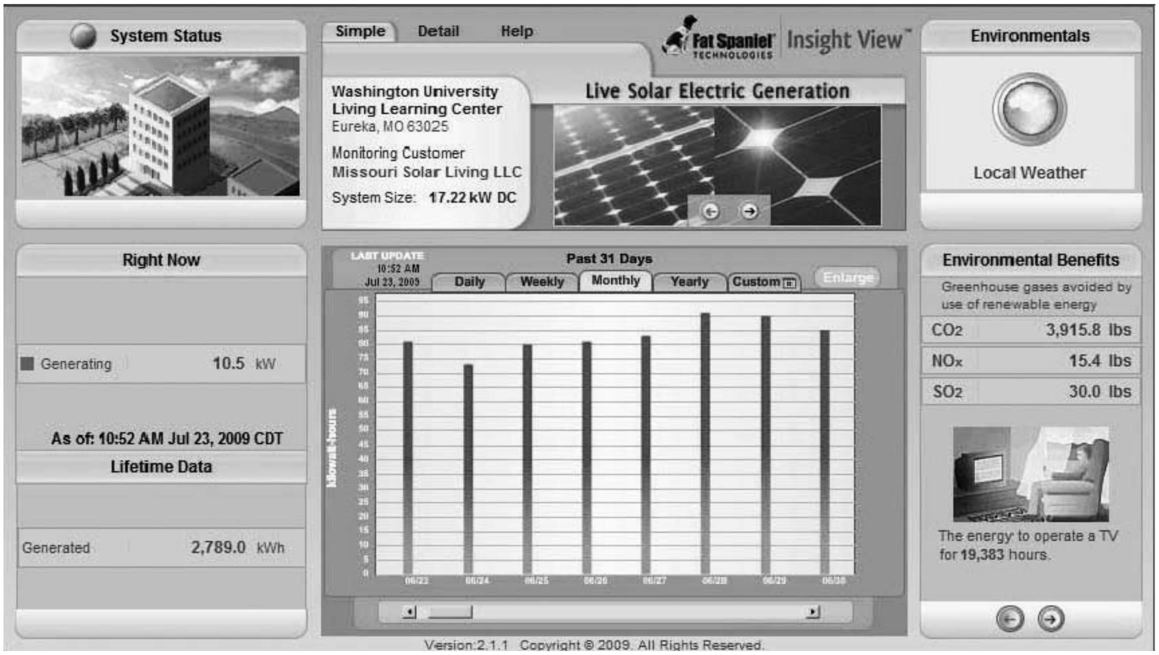
Feedback from the Building

Perhaps the most challenging aspect of the project has been meeting the requirement of energy neutrality, a goal that requires constant monitoring of day-to-day power consumption, education of building occupants, and thoughtful management of the facility by Tyson staff. Essential to this task is software that monitors the building's photovoltaic (PV) power output for a real-time comparison with consumption. The LLC utilizes Fat Spaniel software, integrated within the PV system; a future add-in will generate an immediate comparison between what is produced and consumed. After a peak during the busy summer season, power consumption within the LLC has been reduced by more than 50 percent as facilities staff have learned to maximize the building's energy efficiency and now have a good understanding of the PV systems production limits. The LLC now hovers near energy neutrality and is on pace to be a net producer by summer 2010.

It is now possible to initiate real-time power production from the LLC's PV arrays via the Internet, as well as on the LCD monitor in the lobby of the building. Through the Fat Spaniel system's metering and graphic display interface, users noted a trend toward higher energy use than expected. A range of steps were taken immediately:

- Behavior and operational changes
- Mechanical adjustments to thermostats, pump run times
- Tree trimming
- Daily logging of energy use and posting on the board in the lobby
- Adding back the PV modules that were taken out during the value engineering phase
- Adding capability to the Fat Spaniel system to show real-time energy usage of the building as well as power production

FIGURE 40. Fat Spaniel Metering Display: Production.



The reader also provides real-time access to the building's performance at the following URL: http://view2.fatspaniel.net/PV2Web/merge?&view=PV/standard/Simple&eid=258485.

BEAUTY AND INSPIRATION

The overall design intent for the building was to create a multifunctional, flexible environmental learning center within the very environment being studied. The deteriorated asphalt parking lot in front of the Administration Building has been transformed into a conservation stormwater and greywater garden planted in native perennials with a limestone walkway featuring flagstones gathered from the Tyson property. As visitors meander through the garden, they pass a "rain chain"—tied to a rain barrel—that further expresses the botanical theme with its ornate rain flower motif. This was created by artist Hap Philips, a direct result of trying to meet the LBC's materials distance prerequisites for metals.

The front of the building, just under the eave on the westernmost façade, houses a bat condominium integrated with the façade. Two bat cams may be used to observe the bats in domus once they find their newly-provided habitat.

The main classroom is naturally daylit and naturally ventilated when temperatures allow. Indoor space opens seamlessly into outdoor space through four wide garage doors and an extended canopy that facilitates outdoor classes on the deck even in a light rain. This indoor-outdoor learning opportunity further extends into the site with a landscaped patio framed by integrated bleacher seating on the deck.

All flooring and woodwork used inside are the result of a playful adaptation of the actual wood species that were available, while encouraging the flooring installer to creatively balance the pattern and placement of materials. The end product features a beautiful, naturally-finished hard maple floor within the two larger spaces, paired with a white ash border and black walnut core in the administration wing hallway. All office floors are hickory, while the window, wall, and door trim varies from room to room.

FIGURE 41. Rain Flower for Rain Chain (Hap Phillips, Artist).

FIGURE 42. Bat Houses.

FIGURE 43. Indoor-Outdoor Classroom.

FIGURE 44. Local Stone for Landscape Walkway.

FIGURE 45. Deck and Seating.

Recently, the building received an "Award of Distinction & Citation for Societal & Technical Advancement in Architecture" from AIA St. Louis as part of the group's 2009 Design Awards Program.

IMPROVEMENTS

Another important attribute of a living building is that it offers a truly dynamic environment. The interaction of architects and designers with the people and the building continues through the "performance period" and hopefully will extend beyond it. All participants are seeking better, easier ways to generate performance metrics from the building for monitoring energy and water production and use, as well as useful data for graduate students and the K–12 summer program.

Several items had to be value engineered out of the project, and yet were designed intentionally for inclusion at a future date. These included:

Modular Green Roof (on low roof area)

The Center's lower roof was engineered to accommodate a green roof, most suitably a modular tray system that could be developed at Tyson by architecture students. This could also lead to comparisons in heating and cooling loads with or without the roof. Benefits include:

- Increased stormwater absorption performance.
- Increased life of the roofing membrane.
- Reduced cooling load due to lower roof temperatures resulting from evapo-transpiration.
- Pedagogical benefit of having a green roof for stormwater quantity and quality study.

Improved and increased monitoring

Adding building monitoring and controls for:

- Building energy consumption, broken down by lighting, HVAC, computers, pumps, etc.
- Water flow from rainwater tank gutter, flat roof gutter, entry roof gutter, consumption at sinks, greywater flow, stormwater volume overflow at rainwater tank and dry creek beds.
- Outdoor ambient conditions, including temperature, humidity, rainwater, cloud cover.
- Indoor environmental conditions, including temperature and humidity.
- Adding a more detailed informational system kiosk in the building lobby.

FIGURE 46. Wood Flooring.

Light Shelves on Exterior and Interior South-Facing Windows

Additional improvements to the building not only increase its performance but also increase the ability of staff, students and researchers to access ongoing and real-time data being generated by the building itself.

CONCLUSION

Within the first several months of the Living Learning Center's competition, its principal purpose—serving as the home for the Tyson Research Center's NSF-funded environmental sustainability outreach program—was being met fully through use of this facility. Yet the building has also attracted great educational and research interest from students in many other schools at Washington University, including those in architecture, engineering, and environmental sciences, as well as professionals and citizens within metropolitan St. Louis. Recently the Concrete Council of St. Louis Presented Vee Jay with an

Environmental Award for their work on the LLC's pervious concrete. Also, the building has quickly become a noted resource for many organizations working to implement the ideals of sustainability on a broader community scale across St. Louis. As use of the Living Learning Center evolves over time and Washington U. becomes more aware of its potential, new uses for this small but adaptable experiment promise even greater discovery.

Another unforeseen consequence of designing within the framework of the Living Building Challenge is the powerful influence of this experience on improving Washington University's facility design processes and guidelines. The LLC represents a new model for how the university facilitates integrated design, how it uses life cycle analysis, and how it properly assesses and implements sustainable design and technology. As a result of this project, several technologies applied to the Center are now being analyzed for further use on Washington U.'s other campuses. As an institution where sustainability is central to its mission and firmly committed to designing, constructing, and operating high-performing buildings, the Center and the LBC have already proven to be transformative catalysts for Washington U., its stakeholders, and its design partners in the course of discovering truly sustainable (i.e., living) design.

FIGURE 47. Sustainable Design Attributes—Exterior.

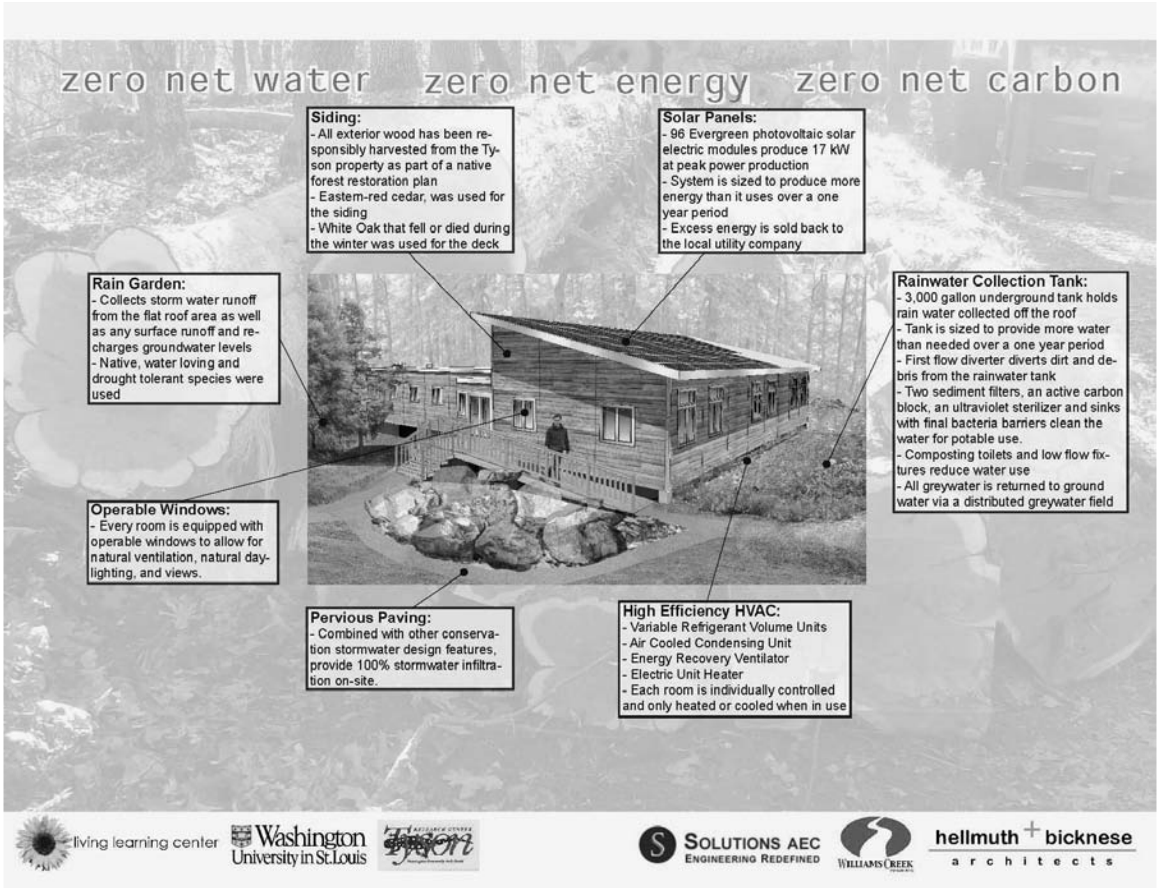
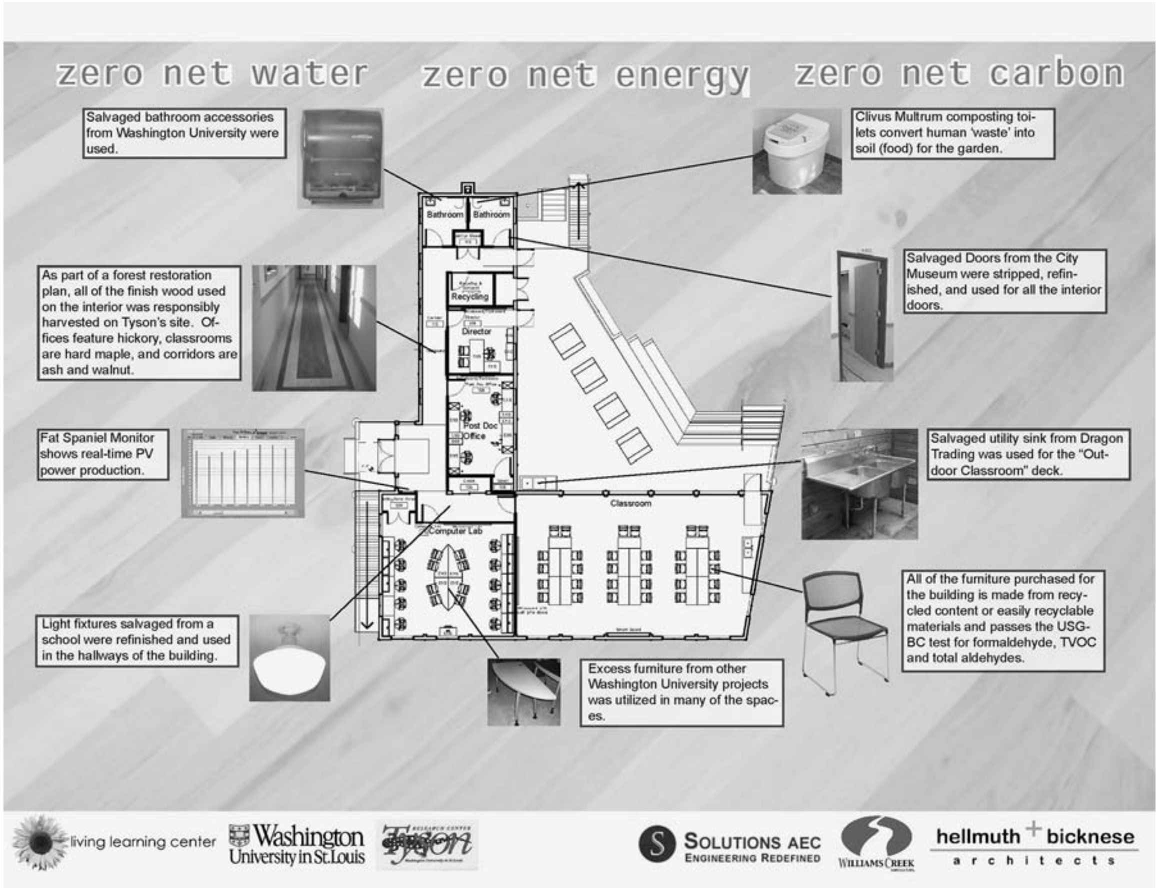


FIGURE 48. Sustainable Attributes-Interior.



"The process to design and construct the Living Learning Center to meet the Living Building Challenge was an extremely demanding, yet rewarding process for Washington University and all of our tremendous partners," said Matt Malten, AVC for Sustainability. "While we are proud and hopeful that our efforts may result in the world's first certified living building, the greatest reward will be for this project to take its place in inspiring and catalyzing the our society to continue a relentless pursuit of creating truly sustainable buildings."

NOTES

1. Berkebile, Robert J. and Jason F. McLennan, "The Living Building", *The World & I*, Oct. 1999, http://www.worldandi.com/specialreport/1999/october/Sa18857.htm.
2. International Living Building Institute, Living Building Challenge Version 1.3, http://www.ilbi.org/the-standard/version-1-3.
3. www.cdmgoldstandard.org.