ABOVE ALL, A LIBRARY exists to serve its community in ways that extend far beyond checking out books. A library in a diverse neighborhood in West Berkeley, Calif., had outgrown its space for vital community programs by the late 2000s. Rather than renovating again to address this problem, the old building was demolished after careful study showed the benefits of starting from scratch. In the old library’s place stands a new zero net energy library that will meet community needs for years to come.
Deciding on Zero Net Energy
The new West Branch Library building is the result of a bond the City of Berkeley passed in 2008 to modernize or replace its four branch libraries, two years after it passed a citywide climate action plan establishing goals for limiting greenhouse gas emissions.

However, the RFPs for the libraries, long in the making, were not linked to the new climate action goals. Responding to the RFP, the architects saw an opportunity for synergy in recommending a zero net energy (ZNE) library in their proposal for the West Branch Library. Inspired by this vision of a zero net energy library with generous daylight, natural ventilation, and spacious reading rooms and program spaces in response to the needs of its diverse community, the city selected the author’s firm as the architect. The new library is certified net zero energy by the International Living Future Institute.

Funding Zero Net Energy
Incentives from PG&E were tapped to offset some ZNE design fees, establishing the library as a pilot ZNE project for the utility—and ZNE as an official contract goal. This accomplished the single most critical step in achieving zero net energy: establishing a firm early commitment to the goal by

West Branch Library: Through the Years to Net Zero

The West Branch of the Berkeley Public Library is in West Berkeley, near the former industrial section of town, and at the center of its diverse multicultural communities. It faces south on University Avenue near San Pablo Avenue. Its original 1923 building, modeled after the Carnegie libraries, was hidden behind a nondescript 1970s addition. However, the building was still revered by some Berkeley residents. A careful and unbiased evaluation of options was required before a consensus could be built around the scheme for a new ZNE building. A life-cycle cost analysis including both embodied and operational energy and costs indicated the significant savings to be derived from the new building. In addition, replacing the building allowed a better use of the constrained site area and a more open, efficient, flexible, and easily supervised library layout to meet community needs.
### BUILDING AT A GLANCE

<table>
<thead>
<tr>
<th>Name</th>
<th>West Branch Library of the Berkeley Public Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Berkeley, Calif.</td>
</tr>
<tr>
<td>Miles from nearest major city</td>
<td>14 miles NE of San Francisco</td>
</tr>
<tr>
<td>Owner</td>
<td>City of Berkeley</td>
</tr>
<tr>
<td>Principal Use</td>
<td>Public Library</td>
</tr>
<tr>
<td>Employees/Occupants</td>
<td>N/A</td>
</tr>
<tr>
<td>Expected (Design) Occupancy</td>
<td>252</td>
</tr>
<tr>
<td>Gross Square Footage</td>
<td>9,400</td>
</tr>
<tr>
<td>Conditioned Space</td>
<td>8,266 ft²</td>
</tr>
<tr>
<td>Distinctions/Awards</td>
<td>AIA COTE Top Ten 2016; ILFI Net Zero Energy Certified; LEED Platinum</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$7.9 million</td>
</tr>
<tr>
<td>Substantial Completion/Occupancy</td>
<td>December, 2013</td>
</tr>
</tbody>
</table>

### ENERGY AT A GLANCE

<table>
<thead>
<tr>
<th>Annual Energy Use Intensity (EUI)</th>
<th>(Site) 25 kBtu/ft² · yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity (Grid Purchase)</td>
<td>25 kBtu/ft² · yr</td>
</tr>
<tr>
<td>Annual On-Site Renewable Energy Exported</td>
<td>11 kBtu/ft²</td>
</tr>
<tr>
<td>Annual Energy Cost Index (ECI)</td>
<td>$0.05/ft²</td>
</tr>
<tr>
<td>Savings vs. Standard 90.1-2007 Design Building</td>
<td>29% compared to Title 24 (calibrated baseline model)</td>
</tr>
</tbody>
</table>

**ENERGY STAR Rating** Property type is not eligible

### WATER AT A GLANCE

<table>
<thead>
<tr>
<th>Annual Water Use</th>
<th>207,958 gallons</th>
</tr>
</thead>
</table>

### KEY SUSTAINABLE FEATURES

**Water Conservation** Potable water use reduced by 58.2% from the LEED baseline through drought tolerant plantings and low-flow plumbing fixtures;

**Recycled Materials** 11.6% recycled content, primarily in structural steel, rebar, bioswale soil, aluminum windows, miscellaneous metals and metal accessories, acoustic insulation, and acoustic ceilings.

**Daylighting** Library achieves 97% daylighting. Carefully controlled daylight is harvested from skylights and large areas of glazing at north and south façades. South façade uses triple glazing for thermal and acoustic performance. Baffling of direct sunlight minimizes heat gain and reduces glare.

**Individual Controls** Manually operated task lighting and manual overrides for ambient lighting. Windows are normally controlled by BMS for fresh air intake. However, they can also be opened manually for added individual control. The BMS performs a regularly scheduled sweep to close windows as needed to conserve energy.

**Carbon Reduction Strategies** The building’s carbon footprint was reduced through both operational energy reductions (net positive performance) and embodied energy savings. Actual energy use was reduced from the AIA 2030 baseline by 76%, through daylighting, natural ventilation, plug load management, and high performance exterior envelope assemblies. Building materials were carefully selected to minimize embodied energy. For example advanced wood framing reduces quantity of wood used and reduces milling waste.

**Transportation Mitigation Strategies** There is no on-site parking. Patrons and staff can rely on an efficient public transportation system, including four bus routes immediately adjacent, BART (rapid transit) within one half mile, and a bicycle boulevard one block away.

**Other Major Sustainable Features** Storm water management: all storm water runoff filtered, cleaned, and detained before discharge to city storm drain system; all roof runoff collected in flow-through planters.

**Thermal comfort and IEQ** A radiant floor supplied by solar thermal panels and heat pumps provides comfortable heating and cooling without a traditional duct system; ceiling fans and transfer vents provide ventilation for smaller rooms; a garden in the back creates a cooler microclimate near the fresh air intake.

### BUILDING ENVELOPE

**Roof** Type TPO single ply roofing over wood-framed 24 in. o.c., w/ 12 in. of mineral wool insulation plus 3 in. of rigid XPS

Overall R-value 55

Reflectivity Initial Solar Reflectance 0.79
Aged Solar Reflectance (3 years) 0.78
Thermal Emittance = 0.85
Initial SRI = 98
Weathered SRI = 81

**Walls**

Type Fiber-cement panel rainscreen, 2.5 in. × 7.5 in. glulam studs at 24 in. o.c., with mineral wool insulation R-28

Overall R-value 25.5

**Basement/Foundation**

Slab Edge Insulation R-value 0
Basement Wall Insulation R-value N/A
Basement Floor R-value N/A
Under-Slab Insulation R-value 9 (total R-value of floor assembly)

**Windows**

Effective U-factor for Assembly 0.26
Solar Heat Gain Coefficient (SHGC) 0.27
Visual Transmittance 0.64

**Location**

Latitude 37.52
Orientation S 80 degrees 38’ 30” W

### BUILDING TEAM

Building Owner/Representative Berkeley Public Library

Architect HED

Construction Manager Kitchel CEM

Mechanical Engineer HED and Timmons Design

Electrical Engineer HED

Energy Modeler HED

Structural Engineer Tipping Mar

Civil Engineer Moran Engineering

Landscape Architect John Northmore Roberts & Assoc.

Lighting Design Max Pierson Minuscule Lighting

LEED Consultant HED

Commissioning Agent Orry Nottingham
the client, the key stakeholders, and the design and construction teams.

With the ZNE analysis fees partially offset by the incentive, another critical cost hurdle was to bring the construction cost estimate within the budget. Initial estimates were high. However, rather than eliminate the photovoltaic and solar thermal panels or the high performance envelope, the façade was simplified with a reduced quantity of glazing. In the end the cost was kept in line with that of the other branch libraries that did not attain ZNE.

**Energy**

Due to its tight urban site, the building’s limited roof area and solar access were primary drivers of the configuration, dictating the target EUI that would make ZNE feasible. Through successful integrated design, the design team was able to maximize the renewable energy generation while also finding opportunities to capitalize on other design features. Though it ended up a one-story building, its height was raised to minimize the roof shading caused...
by the adjacent three-story building to the east and to increase the civic presence of the building on the street, another key goal.

The roof design became the main focus of the integrated process, as competing needs for solar panels, natural ventilation, and daylight were reconciled. The design evolved into a tight composition of alternating south-facing solar panels and north-facing clerestories, with the end result of both ZNE performance and a bright, airy interior.

Berkeley’s temperate climate is enhanced by moderate ocean breezes flowing in from the west. Early design concepts sought to use these breezes for natural ventilation and cooling. However, the building is located on a major street with heavy truck traffic idling just beyond the lot line, which produced conflicting requirements

Figure 1  SOLAR ACCESS ANALYSIS

The dense urban context required a detailed solar access analysis to confirm the potential for solar energy generation on site.
Figure 2 NATURAL VENTILATION, DAYLIGHTING, AND SOLAR ENERGY STRATEGIES

1. Site Selection Urban Site, No Onsite Parking, Promotes Public Transportation
2. Storm Water Technology Gardens and Low Flow Planters
3. Native Trees and Planting Ecological Education Opportunities
4. Building Material Thermal Efficient High Performance Rain Screen - R31
5. Building Material Thermal Efficient Cool Roof - R40
6. Building Material FSC Certified Wood - 97%
7. Natural Ventilation Operable Windows for Air Intake
8. Natural Ventilation Venting Skylights for Air Exhaust
9. Natural Ventilation Wind Chimney for Air Exhaust - Stack Ventilation/Bernoulli Concepts
10. Daylighting Operable Skylights
11. Daylighting Sunshading for Direct Southern Light Over Triple Glaze Low-e Curtain Wall
12. Solar Thermal Radiant Floor
13. Solar Thermal Hot Water Panels
14. Energy Generation PV Panels - Feed back to Grid
15. Prevailing Ocean Breeze Creates Negative Pressure at Backside of Front Facade - Pulls Air out of the Building

Integrated strategies for natural ventilation, daylighting, and solar energy included an innovative wind chimney that provides cross ventilation while protecting the library interior from street noise.
to protect the building interior from truck noise and exhaust fumes. The team devised a strategy to bring in fresh air from the back of the lot, from the more vegetated residential zone.

To create cross-ventilation without opening onto the street, a wind chimney was developed that uses the prevailing winds to create a negative pressure on the back side of the wind chimney, pulling fresh air into and across the building from the north side. As an added benefit, the wind chimney also provides additional rationale for extending the height of the street façade.

Initial design concepts were tested through a full range of building simulation programs, including whole building energy modeling, thermal comfort analysis, daylight analysis, and computational fluid dynamics (CFD), to optimize the design for greatest efficiency, comfort, and delight. The most surprising result came from the CFD, in testing the efficacy of various interior building shapes to facilitate airflow across the room. While intuitively a wedge shape appeared to reinforce the airflow up to and out of the wind chimney, in fact this shape caused more turbulence, impeding airflow, than the alternate box shape.

To make the most effective use of the temperate Bay Area climate, a mixed-mode system was established that minimized the need for active heating and cooling systems. In all seasons, the high performance envelope maintains relatively stable conditions in the interior to require less active heating and cooling. In the heating season, outdoor air requirements are fulfilled through air intake through the north windows. Radiant grilles on the interior side of these windows pre-temper the air before it enters the space. Additional heating, if required, is provided by a radiant slab. Both the radiators and the radiant slab are 

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**Figure 3** DAYLIGHT MODELING

Daylighting simulations optimized the skylight and fenestration design.

**Figure 4** FLOOR PLAN

The floor plan layout maximizes flexibility of use with an open reading room subdivided with furniture for separate age groups, with a community room that doubles as an additional reading area, and with a second entry that provides after hours access to special program areas.
Balanced and carefully controlled daylight is harvested from skylights and from glazing at north and south facades.

**Figure 5  BIOCLIMATIC DESIGN**

The Mixed-Mode Operation System shifts mode in response to changing atmosphere conditions, to maintain interior comfort + air quality.
supplied by a solar thermal system, backed up by an electric boiler.

In the shoulder seasons, the ocean breezes work with the wind chimney to provide adequate natural ventilation. The space is kept cool by opening additional operable vents at the skylights, exhausting any warm air building up at the ceiling. As the weather moves into the cooling season, the operable skylight vents close again, and the radiant slab absorbs the heat from the space as cool solution flows through the piping.

The natural ventilation strategy used in the main reading space is also carried through the smaller staff, community, and program spaces. Here transfer ducts are used to facilitate airflow between spaces while blocking sound transfer.

**Water Conservation**
Achieving ZNE goals is inseparable from other facets of sustainable design, due to the interdependence of energy use, water use, storm water management, resiliency, comfort, resource conservation, interior environmental quality, and beauty. At the library, a well-orchestrated storm water plan for on-site storm water retention involved subdividing water flows to planters in each of four quadrants of the site. When a subcontractor proposed an alternative photovoltaic panel layout, it was rejected as it disrupted the carefully balanced quantities assigned to each quadrant.

**Maximizing Building Use**
A key determining factor of the building layout was maximizing building use throughout each day and week. As a true center of the community, providing not only traditional library functions, but also community space and robust literacy programming, access to the community and program spaces was required outside of library staff hours. This was accommodated through a side door to the northwest section of the building, while shutting off access to the rest of the library. Further flexibility of use was provided by situating the community room where it can serve as an

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**Figure 6 WHOLE BUILDING ENERGY ANALYSIS**

This chart compares the predicted and measured EUI against various benchmarks. Predicted and measured renewable energy generation is also shown to confirm ZNE performance.

**Figure 7 MEASURED MONTHLY ENERGY USE 2014**

- **Plug Load**
- **Lighting**
- **Cooling**
- **Solar Thermal**
- **Photovoltaic Panels**
Lessons Learned

- A positive lesson learned from the West Berkeley library project was the essential need to confirm team commitment to the zero net energy performance target at the earliest, pre-contract stage to ensure success.

- A second lesson is the importance of anticipating possible and likely user behaviors, and accommodating for them in the design. During design, construction, and post occupancy, the design solutions will only be successful to the extent that the goals are communicated clearly and at regular intervals to the owners, occupants, and users of the building. At the West Berkeley branch, user attitudes toward the lighting and operable windows impacted the effectiveness of these solutions, requiring some adjustment of energy efficiency goals, of user behavior, and of BMS protocols post-occupancy.

- A third lesson, linked to the second, is that resilient long-term solutions are the simple solutions, easy to understand, to use, and to maintain.

- As a fourth lesson, achievement of specific energy performance goals depends on clear criteria for monitoring and verification in the contract and an accounting for both hard costs and ongoing staffing hours in the construction and operations budgets.

- On the owner’s side, the city concluded that the contractor procurement process relied too heavily on choosing the lowest bid, and that a more holistic selection process might have facilitated a more direct achievement of best value for the project. In addition, a more robust life-cycle cost analysis may have helped the specification and value engineering decisions. And using a financial capital outlay model for city projects that more fully leverages projected operations and maintenance savings into capital budgets would allow a more equitable evaluation of cost for long-term value.

- Additional quiet reading area when not used for a group function.

- To make the best use of staff resources, the circulation and reference desks were combined into one central location that offered excellent sightlines of all reading areas and stacks. Effective energy conservation in a building must look beyond the energy used by active systems of the building and consider how building use and operations can be streamlined, flexible, and multifunctional.

Resource Conservation

Reducing embodied energy through resource conservation was a focus throughout material selection and specification. Advanced wood framing techniques maximized exterior wall insulation and strength with a minimum of material. Custom engineering of the framing for the exterior fiber cement panels reduced the quantity of steel by 30%.

Lighting

Design teams must also recognize that at times the most obvious engineering solution may not be the preferred solution for the client. In the case of lighting design, preconceptions regarding the appropriate light levels to create an inviting space did not align with the established light levels required for various tasks. As a result, the client decided during construction to add more light fixtures to increase the overall ambient light level, even though the light levels at the reading tables and book stacks were adequate.

In addition, additional lights are kept on at times as an indicator that the library is open. This became a factor in why the first year’s measured energy consumption exceeded the calibrated modeled energy consumption. Fortunately, the energy generation also exceeded expectations, due to an upgrade in panel efficiency made feasible with lowering panel costs over the course of design, bidding, and construction.

After Occupancy

The importance of long-term owner and occupant engagement with the net zero concept cannot be overstated. Though building monitoring and both on-site and online energy dashboards were included in the contract specifications, only a fairly limited interface and set of data points could be included within the budget. Over the years since occupancy, there have been ongoing efforts to upgrade the system. At the same time, discontinuities in staffing and malfunctions of equipment or Internet connection have impeded a continuous collection of data. Setting a goal of ZNE performance entails maintaining adequate funding for the hours required to measure, evaluate, and respond to the performance data.

Post occupancy, an issue developed with the operable window actuators and the operation of the solar radiators concerning the interface between the time clock schedule, the interior and exterior conditions, and the open/closed status of the windows. It remains a challenge to successfully commission more complex systems that depend on unpredictable user behavior and scheduling changes; striving for simplicity in integrated design solutions leads most reliably to resilient high performance building.

Despite various challenges, the library has succeeded well beyond its original program requirements, setting a precedent for Berkeley’s fulfillment of its climate action plan, and becoming an inspiring center of its community.

ABOUT THE AUTHOR

Sylvia Wallis, AIA, LEED AP BD+C, is an associate of architecture and design at HED in Los Angeles.