While some buildings wear their net zero design on their sleeves, the Packard Foundation Headquarters employs energy-efficient and sustainable technologies in a more understated fashion. Slanted roof lines, extensive exposed wood and transparent spaces create a warm, classic Californian feel to the space. The net positive energy building has achieved the Packard Foundation’s goal of creating a building that is attractive, innovative, healthy and comfortable. The project received ASHRAE’s Award of Engineering Excellence in 2014. It is only the fourth project to receive it since the award’s creation in 1989.
The success of the design can be measured on several fronts. The in-operation energy use intensity of 23.5 kBtu/ft²·year has been decreasing as enhanced commissioning continues. The building confirmed its net-positive energy status in July 2013, generating 418 MWh of electricity in the first year of operation with on-site 303 kW photovoltaic rooftop panels. It consumed only 351 MWh of electricity and zero natural gas. (See more at “Tracking the Path to Net Zero Energy,” tinyurl.com/bnx9meg.)

Occupants have responded to comfort surveys reporting superior comfort, acoustics, healthy indoor air, abundant natural light and an overall pleasant environment. Post-occupancy feedback shows 97% of occupants are satisfied with the building overall, and thermal comfort satisfaction ranks in the 96th percentile.

The building tells the story that it is possible to reach energy neutrality without sacrificing comfort. In fact, the design strategies such as operable windows and blinds, individually dimmable lighting and a dedicated thermostat per chilled beam in each office have actually enhanced comfort by giving more control to users.

Integrated Design
Exercising the process of integrated design, the team of architects, landscape architects, engineers, designers, and contractors worked together to complete a climate and weather analysis and a daylight and sun-path analysis; established proper architectural massing; detailed an advanced envelope design; and initiated an exhaustive study to predict and minimize plug loads—all before the team made any major decisions about the building’s design.

The analysis-driven design methods led to a desirable solar orientation, external shading, a 50% increase in framing member spacing, deeper wall cavities, higher insulation values and continuous...
Overhead active chilled beams bring comfort and ventilation to one of many collaboration spaces without sacrificing architectural delight.

insulation for increased overall thermal performance, a well-insulated floor slab and roof, and R-6 triple glazed windows with thermally broken fiberglass frames and argon fill. The envelope upgrades allowed the mechanical engineers to get rid of perimeter heating systems.

The enhanced envelope also created excellent stability, control and symmetry of indoor temperatures. The courtyard and narrow floor plan design allows full capability of natural ventilation and optimized daylight.

The weather and sun-path analysis optimized the custom design of solar controls and motorized shades for avoidance of unwanted solar heat gain. The analysis also informed the arrangement of the floor plan. These up-front, analysis-driven decisions are imperative to the overall success of the mechanical design, and the design team considers them part of the mechanical design.

The Packard Foundation, in keeping with its philanthropic mission to drive a sustainable future, encourages replication of its headquarters.

The design team generated a base design “replicable warm shell” that can be functional and energy neutral in many climates, while leaving the aesthetics up to the designer. The Packard Foundation web site, shares information to proliferate the positive impact of the headquarters’ green design (see “Sustainability in Practice” at tinyurl.com/ntu2rwn).

**Lighting and Daylighting**

The building is designed to be fully daylit. The daylight design put a priority on avoiding excessive brightness in daylit areas. Because the building is oriented 58 degrees off a true east-west axis, external fixed shading devices are supplemented with
exterior automated shading blinds.

Internal dimmable ambient lighting is coupled with LED task lighting. Extensive daylight modeling of the spaces during design helped optimize window and shading device placement.

**Water**
California’s prolonged and worsening drought highlights the need for leadership in sustainable water practices and underscores the value of broadly applicable water efficiency strategies. The site landscaping comprises various native, drought-resistant plantings watered via a digitally controlled drip irrigation system.

All of the rainwater falling on the building roof is captured and stored in two 10,000 gallon storage tanks, one each dedicated to meeting 60% of irrigation and 90% of toilet flushing. Potable water use for sewage conveyance is further reduced with the installation of waterless urinals and low-flush toilets.

Low-flow fixtures are used throughout the building at lavatories, sinks and showers. These measures result in a 69% reduction in potable water use compared to the LEED baseline for a typical building. Ninety percent of the rainwater runoff from the maximum storm is managed on site.

**HVAC**
Building mechanical systems serving the indoor environmental quality of the space are at the forefront of the building’s innovation. The mechanical design has led to several awards, including a 2014 First Place Technology Award and the Award of Engineering Excellence from ASHRAE.

- Uses water as the energy delivery medium;
- Moves only the minimum amount of air necessary;
- Avoids reheat;
- Minimizes static pressure drop in distribution; and
- Leverages climate and diurnal temperature swings.

To align with these strategies, the engineering team chose two-pipe active chilled beams as the distribution system.

Active chilled beams operate by
delivering tempered ventilation air to each space, and adjust the temperature of the space by inducing room air with the ventilation air across water coils within the active chilled beam diffuser. They operate elegantly and efficiently with very few moving parts.

Distribution: Active Chilled Beams.
Water carries over 3,000 times the amount of energy per volume compared with air. So, a hydronic distribution system is a much more effective means of delivering heat to and from the occupied spaces than forced air (Figure 2).

The team chose a dedicated outdoor air ventilation system (DOAS) that is decoupled from the heating and cooling needs of the space to avoid unnecessary air delivery. The capabilities of active chilled beams allow the space to be heated or cooled with nothing more than minimum ventilation air by inducing air from the room at a ratio of three parts room air to one part supplied air. A room with increasing cooling needs does not require increasing airflows because variable water flow to the coil within the chilled beam will address variable cooling needs.

At the Headquarters, the ventilation-only air supply needs significantly reduced the airside system capacity in comparison to a traditional variable volume with reheat system. The DOAS ramps up and down based on a target CO₂ level of 700 ppm.

The system has performed well, allowing operating airflows to be less than designed, while still providing comfort by exceeding ANSI/ASHRAE 62.1-2007, Ventilation for Acceptable Indoor Air Quality, by at least 30%.

The ventilation air is delivered to the chilled beams at 68°F during the cooling season, compared with the 55°F air typical of variable air volume reheat systems. This system eliminates energy wasted by reheating overcooled air.

The building does not require perimeter heat. The envelope is enhanced to displace the cost of distributing hot of three parts room air to one part supplied air. A room with increasing cooling needs does not require increasing airflows because variable water flow to the coil within the chilled beam will address variable cooling needs.

David and Lucile Packard were philanthropists long before they helped transform a small electronics shop in their garage into one of the world’s leading technology companies.

David met Lucile on the Stanford University campus, where Lucile served as a volunteer at the Stanford Convalescent Home, which treated children with tuberculosis. Later, the two made philanthropy a family concern by discussing with their children which local organizations they should support. Caring about others and the community around them was a core value.

David believed that “management has a responsibility to its employees, to its customers, and to the community at large.” Under his leadership, Hewlett-Packard pioneered many innovative benefits and management concepts, such as flexible working hours, catastrophic medical coverage, and open offices.

David and Lucile formalized their passion for philanthropy in 1964 when they established the David and Lucile Packard Foundation. For more than 50 years, the David and Lucile Packard Foundation has worked with partners around the world to improve the lives of children, families, and communities—and to restore and protect the planet.

Source: www.packard.org
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water to the chilled beams. Building with the highly insulated walls and triple element glazing only requires morning warm-up, which is accomplished through the use of the DOAS air delivered at 76°F to 78°F.

**Piping and Ductwork.** Next, the engineering team stressed the importance of thoughtful mechanical layout to reduce energy wasted in the distribution of air and water. Friction in ducts and pipes causes pressure drop in the fluid, which drives the sizing and energy use of fans and pumps.

The corresponding horsepower required to push fluid through the system varies by the square of the pressure drop. So a small reduction in pressure drop has a compounded impact on energy savings. The team used larger duct and pipe sizes throughout, and used 45 degree fittings in place of 90 degree elbows wherever possible to reduce friction and energy use.

**Central Plants and Thermal Storage.** The active chilled beam distribution system is complemented by central heating and

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**Key Sustainable Features**

**Water Conservation**
Native drought resistant plants watered via digitally controlled drip irrigation. Two 10,000 gallon storage tanks for rainwater capture to meet 60% of irrigation and 90% of toilet flushing. Overall 69% reduction in potable water use through above measures combined with efficient fixtures, urinals and toilets. Ninety percent of rainwater from the maximum storm will be managed on site through collection and porous landscaping.

**Recycled Materials**
At least 20% of content recycled.

**Daylighting**
Investigated with an extensive daylight model allowing all spaces to be fully daylit. External fixed shading supplemented with exterior automated shading blinds to avoid excessive brightness.

**Carbon Reduction Strategies**
Carbon analysis performed. Emissions reduced through use of a wood/steel hybrid structure and wood-framed walls while the concrete mix featured 70% cement replacement using slag. The total embodied CO₂ of 1,790 tons pays off in 4.4 years when compared to the former Packard Foundation Headquarters yearly operational CO₂ of 409 tons, justifying the construction of a new net zero energy building. Elimination of underground parking structure (reduced embodied emissions by 25% alone).

**Transportation Mitigation Strategies**
Elimination of $8 million parking garage with a Transportation Demand Management program that included a “last mile” shuttle to and from a train and bus transit hub.

**Other Major Sustainable Features**
- Two-pipe active chilled beams heating and cooling distribution with decoupled dedicated outside air ventilation system. Saves energy by reducing air handling equipment and reheating over-cooled air in a traditional variable air volume system.
- Perimeter heating eliminated through enhanced envelope.
- Larger duct and pipe sizes throughout with 45 degree fittings wherever possible.

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**Building Team**

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Owner/Representative</td>
<td>David &amp; Lucile Packard Foundation</td>
</tr>
<tr>
<td>Architect</td>
<td>EHDD Architects</td>
</tr>
<tr>
<td>General Contractor</td>
<td>DPR Construction</td>
</tr>
<tr>
<td>MEP Engineer</td>
<td>Integral Group (Engineer of Record Peter Rumsey)</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Tipping Mar</td>
</tr>
<tr>
<td>Civil Engineer</td>
<td>Sherwood Design Engineers</td>
</tr>
<tr>
<td>Landscape Architect</td>
<td>Joni L. Janecki Associates</td>
</tr>
<tr>
<td>Daylight Design</td>
<td>Loisos and Ubbelode</td>
</tr>
<tr>
<td>Commissioning Agent</td>
<td>Altura</td>
</tr>
<tr>
<td>Net Zero Systems Engineer</td>
<td>Travis McDaniel, Point Energy Innovations</td>
</tr>
<tr>
<td>Building Engineer</td>
<td>Juan Uribe, The David and Lucile Packard Foundation Headquarters</td>
</tr>
</tbody>
</table>
operation, and thermal storage systems retain the process water until it is needed.

The chilled water is produced, without the use of a compressor, by a two-cell, 480 ton cooling tower. The cooling tower operates at night with waterside economizing using the cool night air for “free cooling.” The water from the cooling tower is coupled with a plate and frame heat exchanger and a 50,000 gallon storage tank of 58°F chilled water (compared with 40°F to 45°F water typical of variable air volume reheat systems). When the outside air dew point is above 58°F, heat pumps in the DOAS units dehumidify the

Spaces are designed to provide psychological well-being through connection with nature. Highlighting this connection, the outdoor courtyard is intimately tied to the building as if it is another room.

cooling plants that take advantage of the Los Altos climate and diurnal temperature swings, and by the high performance building envelope. At the Headquarters, the central systems generate chilled water and hot water when outside air temperatures are most efficient for the equipment

Large diameter custom piping crosses the mechanical room at varying angles, a result of using 45 degree fittings in place of 90 degree elbows when possible. The reduction in friction, from the larger diameter and 45 degree fittings, results in an exponential reduction in pump energy.

BUILDING ENVELOPE

Roof
Type: Wood framing, R-32.5 rigid board insulation, standing seam metal roof
Overall R-value: R-35.7
Solar Reflectance Index: 41

Walls
Type: 2 in. x 6 in. wood frame, 24 in. on center with R-19 insulation between framing and R-4.2 continuous rigid mineral wool insulation with furring strips
Overall R-value: R-18.2
Glazing Percentage: 46.3% window-to-wall ratio

Basement/Foundation
Slab Edge Insulation R-value: 2 in. expanded polystyrene (EPS) foam, R-8
Basement Wall Insulation R-value: 3 in. EPS foam, R-12
Under-Slab Insulation R-value: R-8

Windows
Effective U-factor for Assembly: U-0.17
Solar Heat Gain Coefficient (SHGC): 0.25
Visual Transmittance: 0.57

Location
Latitude: 37.38°
Orientation: 328°
LESSONS LEARNED

The Packard Foundation building is a treasure trove of lessons learned. The design and construction team is actively sharing the lessons with the larger building community.

Innovative Buildings Depend on Controls That Work. Several initial problems were encountered, including condensation on the chilled beams when controls were not working correctly. The condensation caused by the control system mistakenly being set at 45°F instead of the 55°F to 60°F design setpoint and many other controls issues were identified and rectified during commissioning. Commissioning is key in all buildings, but is especially so in advanced and more innovative buildings.

Further Reduction of Energy Use. Over the first two years of operation the building engineer played a key role in reducing energy use by an additional 5% to 10% through tuning and more actively understanding the dynamics of the building. Some of the opportunities he found included optimal times to turn HVAC equipment on and off, additional ways to get users to take advantage of the operable windows and further plug load reduction opportunities. This made it possible to go beyond net zero energy to a net positive outcome where the building generates more energy than it uses. Although energy use has been reduced, the occupant comfort level has actually improved. Comfort has always been and will continue to be the Foundation’s number one goal.

Getting Plug Loads Under Control Was Key in Lowering the Size of the PV System. The cost of the PV system was reduced by $170,000 through the use of lower energy office equipment and simple time clock and/or occupancy control of the equipment.

reducing Risk of New Applications. During a cold snap in the first winter of operation, two of the four air-source heat pumps failed due to manufacturing defects. Using this type of heat pump for this type of building was a new application. It is important to design out some of this risk through such things as redundancy, and work with owners to make sure they understand the risks of nonconventional systems.

Computer Notification of Conditions for Natural Ventilation. The manually operated natural ventilation system worked best when users were given clues about when to use it right at their desk instead of near the coffee area. A simple software fix was set up that gave users notification at their computer.

Cost Benefit of Chilled Beams. Although the chilled beam system including water-side economizers came at a 10% to 20% premium over the less energy-efficient variable air volume system, the chilled beam system made it possible to lower the PV system cost by $200,000. The elimination of perimeter heating saved a further $150,000.

Beauty Is Important in Sustainable and Net Zero Buildings. The Packard Building has garnered so much attention and thousands of visitors because it shows the way to buildings with exceptional performance where aesthetics are not compromised. At no time in the design of the Packard Foundation building was there a trade-off between beauty and performance. The two were meant to go hand in hand from the beginning. The incorporation of biophilia and the use of comfort enhancing strategies such as automated and fixed shading systems make the building comfortable, beautiful and a joy to inhabit.

ABOUT THE AUTHORS

Peter Rumsey, P.E., Fellow ASHRAE, is founder and CEO of Point Energy Innovations in Oakland, Calif.

Eric Soladay, P.E., Associate Member ASHRAE, is managing principal of the Integral Group in Oakland, Calif.

Ashley Murphree, LEED AP, is a mechanical engineer at Integral Group in Oakland, Calif.

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Conclusion

The success of a building can be judged by the reaction of its occupants. In the case of the Packard Foundation, the occupants value their comfort as well as protecting the environment. On both accounts, the building has been successful.

Nonetheless, the impact and importance of the project is not confined to the occupants. The true impact will be based on how this building influences the design community in the years to come. ●
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