Stanford University’s Jerry Yang and Akiko Yamazaki Environment and Energy Building (Y2E2) aims to provide watershed solutions in the areas of environment, technology and energy. Completed in early 2008, Y2E2 is the first building in Stanford’s new Science and Engineering Quad 2 (SEQ2). SEQ2 has more than 500,000 ft² of interdisciplinary teaching and research space in four sustainable buildings.
The first of the four SEQ2 buildings, Y2E2 includes, among many others, nine laboratories, two departments (civil and environmental engineering and environmental earth systems science), the Precourt Institute for Energy, and the Ward W. and Priscilla B. Woods Institute for the Environment, together with three of its strategic collaborations (the Center for Ocean Solutions, Water in the West, and Food Security and the Environment). The connective areas of the building enable collaborative work where laboratory researchers can literally bump into and connect with social scientists responsible for absorbing and disseminating research insights.

The design team pursued architectural forms and building systems to meet a LEED Platinum-equivalent level of performance (if Stanford chooses to apply), create an integrated learning environment, and inspire each researcher in their area of environmental interest.

**Energy Efficiency**

Energy performance was optimized through a six-step process that achieved a comprehensive, cost-effective, and prioritized approach to the university’s investment. Steps 1 through 3 emphasized load reduction, passive operation, and efficiency; Step 4 sought out energy recovery opportunities; Step 5 incorporated self-generation; and Step 6 allowed for successful carbon-neutral operation through offsets. As a result, Y2E2 has post-occupancy verified energy savings 44% below ASHRAE/IESNA Standard 90.1-2004.

As this is inclusive of non-regulated/process loads and has been verified through metered data, this is an achievement. Non-regulated loads include those impacts from building systems that use energy primarily for process or industrial purposes. Such energy use results from elevators, building transformers, data centers, consumer electronics, plant and animal life support, and a great deal of laboratory systems.

A few of the more than 1,000 high-performance design elements...
Mixed-Mode Operation  The remaining non-lab areas of the building use mixed-mode operation so building occupants can open their windows during temperate conditions.

Daylight  The interior benefits from abundant daylight via skylights at the atria, façade and room treatments (lightshelves and painted surfaces), seamless integration of dimmable lighting, basement light wells, and interior translucency.

Step 3: Make Building Energy Efficient  
Chilled Beams  are used to heat and cool the conditioned non-lab areas of the building. Active chilled beams use the more efficient water distribution system (pumps and piping), rather than the less efficient air-distribution system (fans and ductwork).

Radiant Conditioning  Radiant floor conditioning is installed at the social lobby entry.

Low Velocity Exhaust  The lab exhaust is designed to operate at a low rate of 1,500 fpm. This rate was

Radiant floors and natural ventilation condition the social lobby. Daylighting and natural ventilation account for much of the building’s energy savings.
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30%
Stanford is situated in a Mediterranean climate with frequent water shortages, and the university recognizes that water would soon be a limiting factor in the campus’s continued development. Therefore, Stanford chose to aggressively pursue water efficiency and alternative water sources.

To address Y2E2’s water performance goals meaningfully, the team took a similar step-by-step approach to that for energy. Steps

**Step 5: Generate Energy**

**Monocrystalline PV**  Y2E2 features three photovoltaic systems (thin film, mono-crystalline, and polycrystalline) so students can compare and contrast performance as part of their education, allowing the building not only to conserve and inspire, but teach as well.

**Step 6: Offset**

**Community Reinvestment**  Full site generation was not feasible for a laboratory building. However, the desire to achieve carbon neutral operation has prompted the campus to discuss further opportunities through purchased offsets and community reinvestment.

**Water**

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LUNGS OF THE BUILDING

The atria act as the building’s lungs, passively drawing air through natural buoyancy and cross-driven pressures up and out of the louvers near the apex (Figures 1 through 3). Evenly positioned throughout the building, they are integrated into the building layout, allowing direct connection and natural ventilation for all the perimeter offices along the entire façade.

The atria’s openness to light, sound, airflow, and temperature variation established itself early in the project as a critical key to the project’s success and as overlapping performance challenges to be solved by the fire, lighting, acoustics, and mechanical engineering teams. The design team’s overall task was to create spaces comfortable for the occupants and that form an integral part of the building’s passive ventilation and smoke release schemes.

Early in the design process, lighting engineers studied the atria shape and form in respect to the sun’s path through the sky. Based on angle studies in conjunction with the architectural team, three of the atrium openings were refined to be widest near the top of the building, and narrowest at the base (Figure 4).

This design allows the floor at each level to extend a little below the opening in the floor above, with more floor space at the south sides of each atrium. These receive abundant ambient light, as direct solar light primarily lands at the north. The south sides are ideal locations for meeting rooms with glass walls, open to ambient light and visually connecting to the building’s activities.

With the shape defined, the architectural program for the atria was refined to include common work spaces, meeting rooms, and informal gathering spots. With so many activities needing to occur in areas with abundant sunlight, controlling glare and maintaining visual comfort were critical concerns for the design team.

Acoustic challenges due to openness and visual transparency were addressed by selective material treatment and appropriate systems selection to maintain NC40-45 (atria) and NC35-40 (offices/labs).

Modeling shows natural light penetration at the atria. Three of the atria openings were designed to be widest at the top of the building, allowing each floor to receive abundant ambient light.
Stanford has invested in a reclaimed water system to serve more than 2 million square feet of development and reclaim approximately 60,000 gallons of water per day for non-potable use. Metered water use shows that Y2E2 consumes one-sixth of the water of a similar laboratory building on campus.

Partly as an extension of the work at Y2E2 and the SEQ2,
The Y2E2 building was constructed in just over two years using integrated project delivery and preplanning that combined the efforts of the design team, client, and contractor. This halved the typical building process time.

Adaptive Comfort  Leveraging the adaptive comfort criteria of ASHRAE Standard 55-2004, and through computational analysis, the designers were able to codesign the...
Cost
During design and construction, the team closely tracked and discussed the sustainability cost premium. Individual design elements were broken out from the cost estimate and summed. Its progression started from an early estimate of +9.8% to a final estimate of +0.9% to +4.6%. The ambiguity in the final range reflected the integrated design of components that could not be dissociated from the whole (e.g., atria).

Y2E2 will recover the marginal costs of its energy design measures in only four years, which is well under the university’s 10-year benchmark, yielding a 20%+ return on investment.

Environment
Energy used in buildings generates an estimated 98% of Stanford’s carbon emission on campus; the remaining 2% is from vehicles. Annual consumption data for the

north- and east-facing offices with adequate façade opening and solar protection to maintain comfortable conditions with no mechanical cooling or forced ventilation.

Multitasking Fume Hoods
Instead of double-ventilating spaces, the design economizes by using multitasking fume hoods.

Active Chilled Beam (ACB)
Y2E2 is the first installation of its kind in California and among the largest buildings in the country to install ACB.

Heat Pipes in Lab Airstream
By using a physically separated passive solution that does not depend on moving parts, cross-contamination is avoided and maintenance is reduced.

Natural Smoke Ventilation System
California fire-safety codes require smoke control in atria interconnecting three or more stories. Instead of providing the usual mechanical exhaust systems at great expense to the owner, the fire engineers chose to capitalize on Y2E2’s natural ventilation design and deliver a passive smoke evacuation system (Figure 5).
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CO₂ per kWh based on Pacific Gas & Electric data). Y2E2’s source of power is the campus cogeneration facility that is running 100% on natural gas (at 53.06 kg of CO₂ per MBtu of natural gas).

Annual heating savings (8,761 MBtu) and chilled water savings (2,986 MBtu) result in a reduction of an additional 618 metric tons of emissions. This brings the total emissions reduction to about 841 metric tons.

First year verifies that Y2E2 consumes 50% less energy than similar laboratory buildings in Stanford and thus sets an improved benchmark for future campus buildings.

Y2E2’s energy savings equate to an annual CO₂ emissions reduction of 223 metric tons (at 0.524 lb CO₂ per kWh). This is a significant achievement and demonstrates the effectiveness of the building’s energy-saving measures.

**LESSONS LEARNED**

Significant lessons were learned from the post one-year occupant and facilities survey and re-calibration of energy model. Subsequent buildings at Stanford, including the Huang Engineering Center (130,000 gross square feet), Nanocenter (105,000 gross square feet), and LEED Platinum seeking Knight Graduate School of Business (600,000 gross square feet) learned from Y2E2 and have incorporated many of the lessons here.

**Mixed Mode Feedback to Occupants**

BMS feedback systems that informed building occupants via a read-only dedicated BMS web page had mixed success. The building accommodates four atria and each atrium is connected to naturally ventilated rooms. A message such as “Atria A & B: Occupants should close windows” would flash on the BMS web page to inform the occupants in that zone. It was easy for the occupants to ignore these messages or not access the web page regularly.

Subsequent design solutions at the Stanford Huang Engineering Center and Knight Graduate School of Business incorporated window contact strips to better manage mixed mode operation. In these buildings, contact strips at each operable window are connected to the zone HVAC system (chilled beam, VAV terminal). The zone level system will shut off when the occupant opens the window.

**ACB Variable Air Volume Operation**

The VAV operation of the active chilled beams was identified as an additional energy-saving measure. The building design did not incorporate VAV for several reasons. The air volume needed to condition the space is reduced with the use of chilled beams even in a constant volume system. VAV operation optimizes performance beyond that.

**Calibrated Energy Modeling**

A calibrated energy model was needed to effectively incorporate measurement and verification activities into the post-occupancy performance vetting. Without it, the building appeared to be significantly less efficient simply because it was being used more (and longer) than originally modeled.

Server Room Economizer Air: Fan coil units (FCU) serving the IT/electrical rooms were found to maintain a base load of 30 tons through the year. This load could be lowered significantly by introducing outdoor air (OA) economizers to these units.

**Improvement in Submetering Accuracy**

Submeter monitoring of end uses such as lighting, HVAC components, plug loads, etc., should be calibrated and, where necessary, replaced (under warranty). Such detailed information was critical to understanding performance and allowed for targeted investment of operational time and resources.

While submetered data for Y2E2 is not publicly displayed either via light boards or intranet, subsequent buildings have incorporated these systems, generating awareness and allowing building users to take part in the optimization process.
Actual metered data has shown savings to be even greater as the building use has increased (Figure 6). The resulting emissions reduction is estimated to be nearly 1,200 metric tons in the first year of operation.

In response to financial success and positive feedback from users, Stanford has since mandated that a heightened level of performance be pursued on all subsequent buildings in the 2.4 million square feet capital expansion plan. The directive from the board of trustees is that all buildings target a minimum of 30% energy and 25% water reduction. The design team has continued its relationship with the building users and Stanford Energy & Sustainability staff through detailed performance discussions and guest lecturing, underscoring the strong relationships that formed over the course of design and construction.

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