Located near the Mauna Loa Observatory, which has been monitoring atmospheric change since the 1950s, the Hawaii Preparatory Academy’s Energy Lab fits into a Hawaiian tradition of climate change awareness and resource conservation. In fact, it was the first carbon dioxide readings at the Mauna Loa Observatory that brought the concept of global warming to the world’s attention in the 1960s.
strategy. Operable windows combined with high-volume spaces allow for heat stratification and high-level exhaust.

In addition, a mixed-mode strategy—combining natural ventilation and mechanical systems for air distribution and cooling—was developed to accommodate a few spaces that required more stringent environmental conditions and tighter thermal control. The climate-appropriate design helps minimize cooling loads, and the conference room.

The natural daylighting strategy was conducted to assess its stack effect and passive ventilation strategies could work effectively with the building form and interior space volumes and external strong prevailing wind conditions. A folded roof plane on the north side deflects wind, while an open south side provides daylighting and views.

is served by dedicated air handler units. The units incorporate CO2-based demand control ventilation systems to optimize indoor air quality and thermal comfort. These systems have also never been used.

The natural daylighting strategy helped achieve an average monthly lighting energy consumption of only 11.4 kWh in 2010. The strategy was carefully evaluated through simulation analysis to ensure that all spaces had access to daylight with minimum solar heat gains, while maintaining a minimum light intensity of 75 footcandles throughout the building. This analysis helped to correct areas of high contrast, which would have resulted in glare.

Controls, Renewable Energy

In the event that they would be needed, the team specified high-efficiency fans, demand-controlled ventilation, and SEER 16 air-conditioning units in a multi-zone arrangement. A heating system was deemed unnecessary.

The BAS gathers input from more than 250 meteorological, room and system sensors and shuts down certain circuits at scheduled times to prevent passive loads. A meteorological monitoring system records solar radiation (among other things) and can detect PV system failure or a drop in efficiency.

WATER AT A GLANCE

100% of water comes from precipitation; monthly water captured for 2010 (very dry year) was 549 gallons; water used was 411 gallons.
The building’s systems were fully commissioned, and energy conservation is enforced daily by an extremely energy-conscious faculty. Lighting controls include photosensors, occupancy sensors and automatic shutoff controls.

Renewable electricity is produced by a 27-kW photovoltaic (PV) array on the roof that incorporates three different arrays: a north array, 10-kW PV with built-in inverters; a central array, 12.6-kW standard 220-watt PV panels; and a south array, 4-kW bifacial PV panels.

Because the Energy Lab is connected to the rest of the Academy’s campus, it can export excess electricity. The campus, in turn, is connected to the grid, and uses the grid as a battery in times of overproduction, like holidays and weekends. Additional renewable energy systems include a solar water heating system, a small-scale custom radiant cooling system and a planned wind farm.

**Simulation Analysis**

Early in the project, the team assessed two critical goals: first, that the proposed natural ventilation strategy would maintain thermal comfort; and second, that energy consumption would be kept to a minimum. The available benchmarking data was deemed too broad to be adequate, so the team opted for simulation analysis to study these two issues.

**Thermal Comfort.** Getting the natural ventilation strategy right was a vital, key driver to ensure that energy consumption was kept to a minimum. However, ventilating the building uniformly with strong prevailing winds from one side (north) was a challenge.

Extensive computational fluid dynamics (CFD) analysis was carried out in the early design phases to assess the effectiveness of various design options in improving thermal comfort (height of spaces, location of exhaust fans/louvers, number/size of openings, pressure difference) and to inform the building’s shape. Through this process, the design was optimized to provide maximum comfort by passive means.

**Energy.** Dynamic thermal modeling was used to predict energy consumption and the relative savings of various energy conservation measures as compared to a baseline (a minimum code compliant project).
This analysis relied on assumptions made during the design phase regarding climate data, equipment loads and setpoints, occupancy, scheduling and operations.

Post-Occupancy Evaluation
To compare predicted energy consumption with actual results, the team carried out a post-occupancy analysis. This analysis also helped to assess the simulation software’s accuracy in determining thermal comfort and energy performance. The study used data from the building’s comprehensive metering and monitoring system, which tracks energy expenditures, weather and thermal comfort data.

The HPA campus is located at an elevation of 2,500 ft on a leeward mountainside. Information gathered by the BAS from the on-site weather station at five-minute intervals showed that the microclimate at the HPA campus varies significantly from the U.S. Department of Energy’s weather data for the closest site available, Hilo Airport, which is located on the coast 60 miles away at an elevation of just 38 ft.

The average predicted temperature and relative humidity (RH) were higher than the actual (meaning that the actual conditions were more favorable). The average predicted temperature was 73.6°F, and the average actual temperature was 65.1°F; the average predicted RH was 79.6%, and the actual RH average was 76.7%.

In addition, the actual solar radiation was higher than estimated, resulting in more electricity production. On average, the wind speeds were significantly lower than estimated, meaning that the windows could be left open with less risk of excessive wind speed conditions, reducing the need for active systems.

Energy Consumption
During the first year that the Energy Lab has been occupied, it has generated more than twice the electricity it has used. The excess was exported to the rest of the campus. The lab’s electricity consumption was 59.4% lower than predicted, 11 kBtu/ft² (3.23 kWh/ft²). With the lab’s electricity export, HPA realized an estimated savings of approximately $10,200 in 2010, based on $0.35 per kWh.

The actual interior lighting energy use is considerably lower than estimated. Analysis of data from the on-site weather station at five-minute intervals showed that the microclimate at the HPA campus varies significantly from the U.S. Department of Energy’s weather data for the closest site available, Hilo Airport, which is located on the coast 60 miles away at an elevation of just 38 ft.

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In addition, the actual solar radiation was higher than estimated, resulting in more electricity production. On average, the wind speeds were significantly lower than estimated, meaning that the windows could be left open with less risk of excessive wind speed conditions, reducing the need for active systems.
During 2010, the lab averaged 11 kBtu/ft² (3.23 kWh/ft²). Similar buildings on the HPA campus averaged 52 kBtu/ft² (15.2 kWh/ft²).

A spike in energy consumption occurred in January 2010 due to testing, inaccurate settings for some controls, and remote cyber vandalism that caused controls to be activated online. The BAS detected this underperformance and operations staff quickly corrected it (Figure 2).

Predicted, Actual Thermal Comfort
To reaffirm the reliability of computational fluid dynamics simulation results in predicting thermal comfort conditions when using actual climate data, we modified the weather file used by the software (which uses a typical meteorological year based on historical data) to match the actual site weather conditions for Dec. 9, 2010, with data obtained from the on-site meteorological monitoring system. We then ran the simulation to assess what the internal thermal conditions would be. The simulation results showed that the predicted conditions matched very closely the actual internal temperature and relative humidity between the hours of 5 a.m. and 6 p.m.

In this analysis, the predicted average temperature was 69.1°F and the average RH was 61.5%. The actual measured values were 72.3°F and 60.1% RH. The slight disparity can be attributed in part to operable window and occupancy fluctuations throughout the day, and to the effect of environmental conditions in the space on previous days which could not be matched exactly in the analysis.

For 2010, the annual average outdoor temperature in the main workspace, the Lab, was 70.4°F, ranging from 59°F to 82°F, and the actual average RH was 61.5%. The CFD analysis predicted an average temperature of 74.2°F and average RH of 77.9%, due to the higher temperatures and RH from the weather data file available.

The actual measured temperature in the plenum space (where hot air is exhausted) was averaged 76°F, which was higher than the occupied zone below (70.4°F). This was intended by the design and predicted by earlier analysis, showing that the stack effect works effectively.

In summary, the climatic conditions in 2010 were considerably more favorable than estimated (more solar radiation, lower temperature and RH averages), resulting in better performance with less electricity needed for operations and more electricity produced by the PV system.

The building’s energy story is one component of a sustainable design approach that included strategies for land use (the building was built on the only piece of land previously disturbed on the campus), water...
Actual vs. theoretical data: which would you rather have?

“By changing the ethos of consumption among our students, we hope to create change agents, able to redirect the wasteful practices of our present society to more sustainable, aware lives.”
—Dr. Bill Wiecking, HPA Energy Lab-director

more than 90% of them feel they have learned from and are inspired by the Energy Lab, confirming that the vision has been realized. Since the Energy Lab’s opening, the faculty has encouraged energy conservation through the curriculum and by posting signage throughout the building. The students have learned about the building and its renewable energy systems; in addition, they can build and test their own systems. Students also can compare performance with climatic and operational conditions and connect with students involved in similar projects around the world.

The project team hopes that the data pertaining to this building may be useful in establishing new industry benchmarks for other low-energy education design and high-performance buildings in Hawaii or similar climates.

ABOUT THE AUTHOR

Ana Serra, LEED AP is an associate sustainability consultant at Buro Happold and is a lecturer at The Cooper Union and New York Institute of Technology.