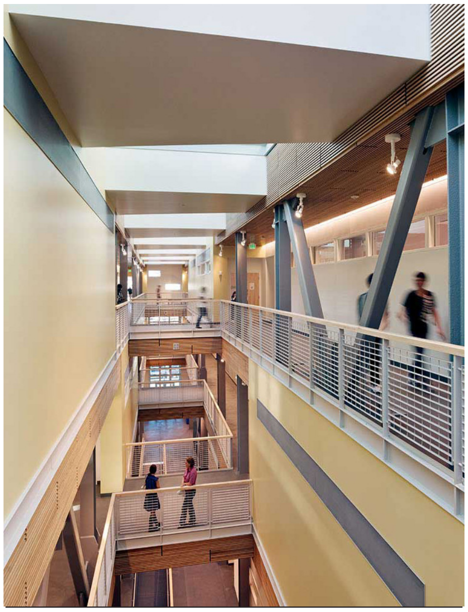
Ultra-Low Energy School Case Study



Both Photos ©Bruce Damonte

OVERVIEW

Building Size: 102,000 SF

Location: San Francisco, CA

Construction Type: New Construction

Completion Date: 2010

Building Type: Education

CA Climate Zone: 3

Energy Use: Electric, Gas

Measured Energy Stats

28	-	0	=	28
BUILDING'S TOTAL EUI		RENEWABLE PRODUCTION RPI		BUILDING'S NET EUI

Site Energy Use Index (EUI) kBtu/SF/year

The Energy Equation: **the building energy use** *minus* **the renewables production** *equals* **the net energy of the building**. Buildings may be 'Getting to Zero' and have a net EUI above zero. If renewable production exceeds energy use its net EUI is below zero (negative) and it is creating surplus energy.

nbi new buildings institute

For more information:
newbuildings.org/zero-energy

SAN FRANCISCO CITY COLLEGE MULTI-USE BUILDING

The San Francisco City College (SFCC) Multi-Use Building (MUB) is a pioneering project for large, low-energy facilities. At 102,000 square feet, the building is one of the largest in the United States to rely nearly entirely on natural ventilation to meet fresh air and cooling requirements.

The SFCC Multi-Use Building houses classrooms, laboratories, a childcare center, café, meeting rooms, administrative offices, and other miscellaneous spaces. Considering that these types of end uses tend to use relatively more energy per area than an average building, the overall energy usage of this building is notably small compared to similar buildings.

Planning & Design Approach

Policy

In 2006, the San Francisco City College Board of Trustees passed a resolution to create a Campus Sustainability Plan[1]. In 200, a Governance Sustainability Committee was formed with faculty, students, staff and administrators which then developed a sustainability initiative that would address environmental, social and economic goals. They later developed the ***Sustainability Plan for Design, Construction and Operations*** as a roadmap for an expanded incorporation of sustainable practices in planning, design, and construction. The Sustainability Plan emphasized energy conservation and onsite and off-site renewable energy opportunities and noted a focus on educating faculty, staff and administrators on their role in achieving sustainable environments and preparing students for

1. San Francisco City College Sustainability Plan for Design, Construction and Operations Part 1, 2009.

Team/Owner Details

Owner: City College of San Francisco

Architect: VBN Architects
Pfau Long Architecture (associate)

Civil Engineer: BKF

Structural Engineer: SOHA

Mechanical/Plumbing Engineer:
Interface Engineering

Electrical Engineer: FW Associates

General Contractor: Lend Lease

Commissioning Agent: WCS/CA

Consultants:
RHAA (landscape)
Arup (environmental building)
FW Associates, HLB (lighting)
Shen Milsom & Wilke (acoustical)
Smith, Fause & McDonald (AV)

Awards

LEED Gold, USGBC, 2012

First Place for Institutional Buildings: ASHRAE Golden Gate Chapter Technology Awards, 2012

Award of Merit: *Engineering News Record California*, 2011

new careers and work experience related to sustainability. The Sustainability Plan set goals for new and major renovation projects as well as existing building operations and upgrades to attain a minimum LEED Silver rating or higher. These metrics allow the project to comply with City of San Francisco resource efficiency requirements, and to utilize the Sustainability Plan's *College's Campus Sustainability Scorecard*. The Sustainability Plan further called out specific energy management protocols generally for regular campus operations, existing and new building commissioning, Energy Star® equipment purchasing, performance measurement, verification and metering, and for all new and future projects to be assessed for renewable energy potential. The *Sustainability Plan* also called for project teams to include a commissioning agent, systematic commissioning plan and report to inform the College's Sustainability Tracking Database. Project teams may also be required when needed, to provide building occupants with facility tours and informational sessions on building systems after occupancy.

Integrated Design Process

The project is a great example of the benefits that come from the early collaboration between the project architect, engineers and other consultants. Through the use of advanced engineering tools, the mechanical engineering team at Interface Engineering worked with the design team, as well as the college project managers to design the MUB to take full advantage of the building site, form, and architecture and achieve optimal passive cooling and overall energy performance. The team employed Computational Fluid Dynamics (CFD) modeling to test designs and ensure the feasibility and performance of a large naturally ventilated building.

Financing

The most significant result of the design is that the cost of the MUB was equivalent to that of a comparable code building with traditional HVAC systems. Through the innovative design, the mechanical engineering team was able to downsize or even eliminate HVAC equipment such as fans, pumps, etc. This downsizing also increased the net square footage available for the building occupants, resulting in a higher value building overall. Using the Construction Manager at Risk delivery model, the project was so cost-effective that the contractor ultimately returned a seven-figure sum back to the college once the project was completed because the project was completed under-budget.

Energy Efficiency Strategies and Features

Lighting and Daylighting

The MUB takes full advantage of daylighting capabilities via passive design of a central atrium which brings light deep into the building interior. This generous daylighting reduces the need for artificial light, which in turn reduces the electrical loads of the building. A variety of shading control strategies were studied to determine value versus costs. Ultimately, natural daylighting and passive heating with limited shading devices were determined to provide greater benefits to the overall energy performance of the project.

Photo ©Bruce Damonte

Natural Ventilation

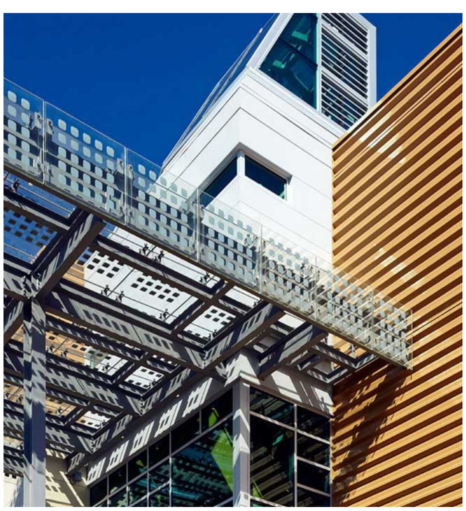
Natural ventilation is the cornerstone of the building design and led the integration of features that take advantage of the prevailing Pacific winds. The central atrium not only provides daylight, but also a means of harnessing the wind power to accelerate a stack effect. By angling the top of the atrium to face the wind, a negative pressure zone on the leeward side of the atrium is detained, thereby creating a mild vacuum which draws air out of the building through louvered openings which can be modulated to control the ventilation. The natural ventilation design is so effective that the building does not require an air handling unit. Vestibules were incorporated into the design to manage high rates of infiltration associated with the entry space.

HVAC

The heating and cooling loads of the building were first reduced by passive design strategies, including a highly insulated green roof. The first option for conditioning the space is wind driven natural ventilation, which uses only the energy required to operate the control system and actuators. When higher loads are present, an in-floor radiant heating and cooling system then comes into action. The radiant system is driven by a ground-source heat pump which boasts higher efficiencies over traditional air-source mechanical systems.

Radiant systems are among the lowest energy intensity forms of mechanical heating and cooling. Given the heat transfer mechanism of radiant systems, set points in the space can also be more relaxed when compared to a traditional forced-air system, which further contributes to the low energy cost.

On a broader scale, the majority of the mechanical loads in the building are satisfied via district scale ground source heat pumps. For a building of this size, the result is that the MUB does not need to have an on-site cooling tower. This lowered first costs and drastically reduces the maintenance costs over the life of the building, and also improves the overall aesthetics, giving the designers more freedom in the design of the roof.



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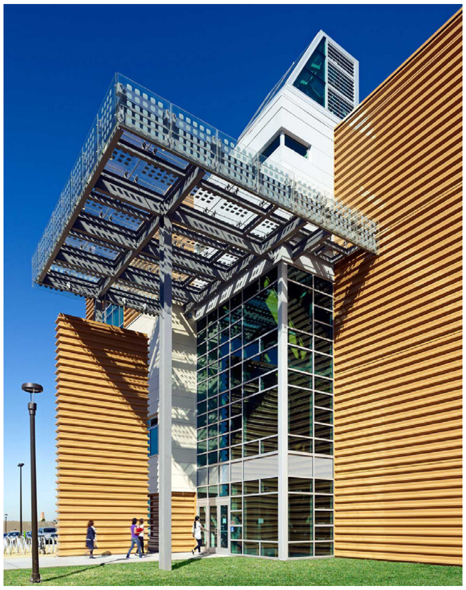

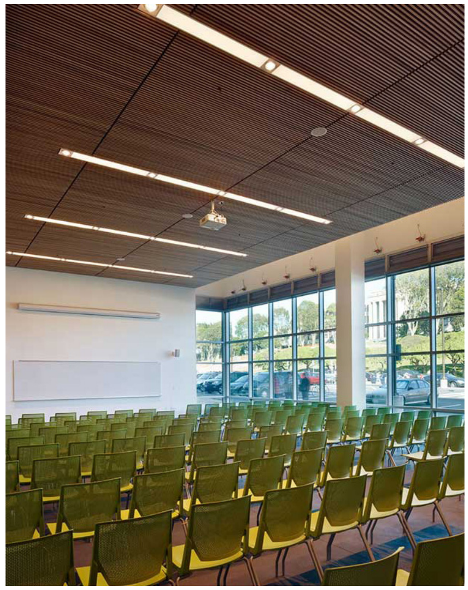

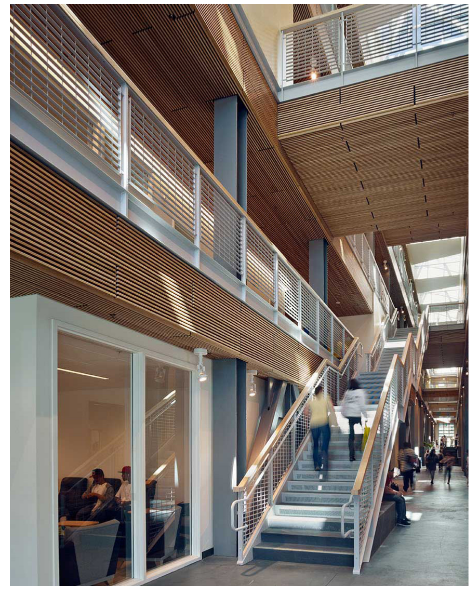

All Photos ©Bruce Damonte

In the summer, the space temperature is allowed to exceed 77°F for short periods of time, which allows for great reductions in energy consumption during spikes in cooling loads.

Controls

Carbon dioxide sensors are used for automatic demand control ventilation of the classrooms. Automated louvers enable the natural ventilation to maintain CO_2 level set points in the space. In addition to being automatically naturally ventilated, operable windows give occupants an opportunity to control their space conditions as well.

In the summer, the space temperature is allowed to exceed 77°F for short periods of time, which allows for great reductions in energy consumption during spikes in cooling loads. With the air movement associated with natural ventilation, internal temperatures can be warmer while still being comfortable.

Plug Loads

Per the Sustainability Plan, the project was required to use Energy Star®-rated equipment throughout the building. While plug loads did not receive a significant focus in the overall planning as a project might today, there was good forethought to include sub-metering of building plug loads with integration in the monitoring system so any issues can be easily identified and addressed as needed.

Renewable Energy Generation and Storage

The building includes a small number of building integrated photovoltaics on the south canopy to generate electricity, although it is not a significant source of generation and functions more as a demonstration feature for the first phase of the project. However, the additional panels are planned for future phases. With added renewables and an already low EUI of 28 kBTU/sf, this ultra-low energy building has the potential to become a zero net energy facility.

Post Occupancy

Commissioning

The SFCC MUB project included LEED Enhanced Commissioning as well as Measurement and Verification. The commissioning agent provided assistance with operator training for facilities staff and a System Operating Manual. The commissioning firm did one-year facility tours with operators to ensure they

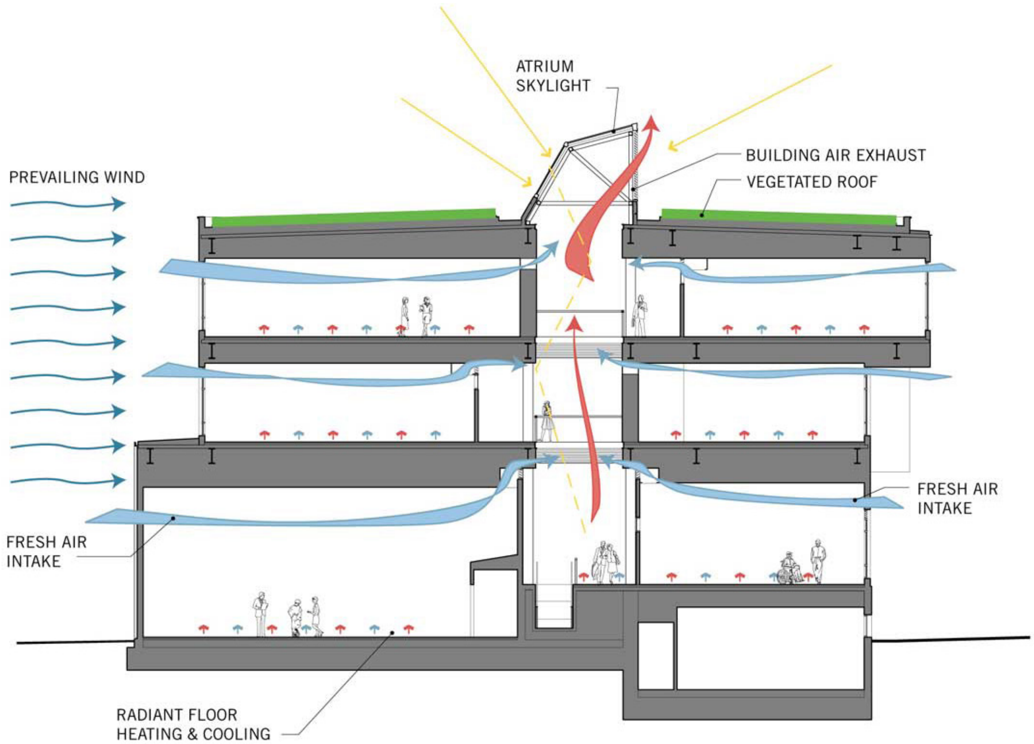

Image © Pfau Long Architecture

A variety of system details ensure the building's long-term performance, including sensors to monitor temperature and air flow and CO_2 content on a room-by-room basis; custom louvered apertures to vent the air; and careful seals for both air and sound separation. The result is the building is 100 percent naturally ventilated.

—Hormoz Janssens, Interface Engineering

understood the nuances of building tuning that were required to address San Francisco's variable climate and adjust for seasonal changes. According to the commissioning agent, the biggest challenge was understanding and controlling building pressurization when using natural ventilation. Controlling ventilation and louvers of the fans required a two-step process that was very unique. Because of San Francisco's strong winds, louvers needed to be closed even at temperatures that would typically leave them open. In addition, the project included a central plant that would provide energy to multiple buildings not yet built, so the team had to be creative when measuring and verifying the system operations. This was done by testing the boilers and chillers at the same time, then running them through a heat exchanger to create enough load to test capacity.

Monitoring

The building design includes sensors to monitor temperature and air flow and CO_2 content on a room-by-room basis. Daylighting sensors in the classrooms were also used to minimize unnecessary electric lighting. Sub-monitoring of mechanical and lighting loads also included to evaluate the design performance compared to the modeled performance.

Behavior

The building is fully automated so occupants have fewer demands when it comes to controlling space conditions. However, all components are displayed, completely visible and intentionally designed to encourage occupant engagement in learning about the building. Operable windows are included in many of the classrooms so there is flexibility for occupants to manage thermal comfort and ventilation, when needed.

Photo ©Bruce Damonte

Successes

The building models for both energy and water consumption predicted 40% better than Title 24-2008 energy code and 30% less water usage than other buildings with a similar scale.

Sub-metering of the energy consumption of plug loads and equipment allow the building owner to maintain a database of energy usage and develop diagnostics to address any issues as they arise. Having this rarely collected data empowers the building owner and operator to optimize the building even further, creating a system of continuous commissioning.

The energy consumption for 12 months of operation came in just above the predicted number of 26.6 kBTU/sf/year. At an an energy use intensity (EUI) of 28, this building is a good candidates for reaching zero net energy, with the addition of on-site renewables in the future.

Lessons Learned

- Harnessing the power of the wind should be balanced with potential challenges that might impact occupants and operators. The acoustics, fluid dynamics, and overall functionality of the system needs to be carefully considered and modeled throughout the design process.
- Training was a challenge in part due to major facilities staffing changes and a desire to occupy the building prior to fully completing the system tuning.
- Naturally ventilated buildings with stack effect can have too much infiltration at entryway doors. Vestibules were added to address this potential challenge.

For More Information

- San Francisco City College Sustainability Plan for Design, Construction and Operations Part 1, 2009 www.ccsf.edu/Offices/Research_Planning/pdf/SustainabilityPlanPart1Dec09.pdf
- ASHRAE Journal, May 2013. "Passive Cooling for School". Hermoz Janssens http://bookstore.ashrae.biz/journal/download.php?file=May2013_054-061_technology-award_Janssens.pdf

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