Tahoe Center for Environmental Sciences, Incline Village, Nevada
Photo credit: Vance Fox, Courtesy of Collaborative Design Studio

Innovative Mechanical Designs in the Sierras

TCES BUILDING FACTS:

- Construction: May, 2005, to August, 2006
- Project Cost: $19 million
- Building Size: Three stories with a basement providing 45,000 square feet (ft^2) of academic and research space
- Owners: A collaboration of Sierra Nevada College and the University of California, Davis, in partnership with Desert Research Institute and the University of Nevada, Reno

Introduction

The Tahoe Center for Environmental Sciences (TCES) is a three-story, 45,000 ft^2 building on Sierra Nevada College's Lake Campus. Located in Incline Village, Nevada, the building serves as a research laboratory for scientists and students working in the Lake Tahoe watershed region, and includes lab space, offices, classrooms, teaching labs, and various support spaces. Designed by the Collaborative Design Studio (formerly Lundahl and Associates) of Reno, and constructed by Turner Construction, the project demonstrates how an ambitious project team can successfully reduce energy usage by implementing a variety of innovative mechanical designs at minimal additional first cost.

The project goal was to build an energy-efficient environmental laboratory and teaching facility sensitive to its location and purpose, while not sacrificing safety or comfort. To accomplish this goal, the design team turned to Rumsey Engineers, an award-winning mechanical engineering firm with a proven track-record in innovative energy-efficient design. From the beginning, Rumsey Engineers said "the first and foremost priority of the design team is to provide a HVAC system that meets or exceeds all of the requirements of the building users." According to Ryan Stahlman of the Collaborative Design Studio, "the architects, client, engineers, and general contractors worked together from day one with a very high level of commitment to create innovative solutions for the building."

The project was awarded the USGBC LEED® (Leadership in Energy and Environmental Design) Platinum certification in May, 2007, achieving 10 points in the Optimizing Energy credit category for an estimated energy savings 60 percent better than ASHRAE baseline. In reality, the building is performing slightly better than predicted (see *Actual Building Performance*) and serves as an exemplary case study for high-performance laboratory design. "We were able to achieve a LEED Platinum certification in a laboratory building, on a site which receives 200 inches of snow a year, 6,500 feet above sea level, while working with one of the strictest regulatory agencies in the country for only $1.1 million [~ $23.5/sf] more than what we would have spent for a LEED Silver building. Pretty exciting," noted Jim Steinmann, Sierra Nevada College's Owner Representative. The array of technologies employed at the TCES to achieve exemplary performance includes: active chilled beams, off-peak use of a cooling tower, and heat recovery from a cogeneration plant.

Ventilation Requirements Decoupled from Heating and Cooling Loads

In any laboratory design, the first priority is proper ventilation. To meet safety requirements, a fixed amount of single-pass (100-percent outside air) ventilation is required. However, as typically planned, laboratory mechanical system design – air change rates, sizing of air handlers and ducting, etc. – is determined by cooling loads over and above ventilation requirements, greatly increasing energy consumption. By decoupling sensible heating and cooling from the ventilation and humidity control functions, the mechanical engineers were able to significantly decrease energy usage for the TCES. The novel design uses the air-handling system to provide ventilation air only to the laboratory and offices, and provides heating and cooling through separate hydronic systems. Duct sizes and fan energy use are greatly reduced throughout the building as a result, allowing for lower floor-to-floor heights and less building skin, which garners additional space efficiencies.

Hydronic systems are used to heat or cool the building. They send either hot or chilled water to a space to provide on-location conditioning, as supply air is passed through the tempered hydronic coils. Since water has a higher heat capacity than air, water can carry either warmth or "coolth," more efficiently (smaller volume, less losses) than air to achieve the same amount of heating or cooling. While the individual conditioning requirements for the TCES laboratories and other building spaces differ, a single hydronic heating and cooling plant serves the

INNOVATIVE FEATURES OF THE LEED PLATINUM BUILDING INCLUDE:

- Active Chilled Beams
- Thermal Storage / Off-peak use of Cooling Tower
- Heat Recovery from Cogeneration
- Effective Ventilation
- Aggressive Daylighting
- Rain Water Recovery

Photo Credit: Jeff Dow
Courtesy of Collaborative Design Studio

TCES PROJECT TEAM

- ARCHITECT:
  COLLABORATIVE DESIGN STUDIO
  (FORMERLY LUNDAHL AND ASSOCIATES)
- CONTRACTOR:
  TURNER CONSTRUCTION COMPANY
- MECHANICAL ENGINEER:
  RUMSEY ENGINEERS
- ELECTRICAL ENGINEER:
  INTEGRATED DESIGN ASSOCIATES
  (IDEAS)
- STRUCTURAL ENGINEER:
  JOHN A. MARTIN & ASSOCIATES
  OF NEVADA
- LIGHTING DESIGNER:
  DAVID NELSON & ASSOCIATES
- ACOUSTICAL CONSULTANT:
  MCKAY CONANT BROOK, INC.
- LABORATORY CONSULTANT:
  RESEARCH FACILITIES DESIGN
- LEED CONSULTANT:
  ARCHITECTURAL ENERGY CORPORATION

"The occupants love the operable windows and the natural light. . . we are very pleased with the building."

Jim Steinmann,
Sierra Nevada College's
Owner Representative

entire building providing additional opportunities for equipment efficiencies (See *Heating and Cooling Loads Met Efficiently*)

One air handler serves the office, classroom, and support spaces. A second air handler serves all of the laboratory spaces. Both air handlers are designed for 100 percent outside air (no return) to meet ventilation requirements, and are also equipped with an atomizing humidification system to maintain a minimum interior humidity of 20 percent during the winter months. In the laboratory spaces, air flow is tied only to ventilation requirements and air volume is not varied in response to space loads. In the offices and classrooms, ventilation is varied according to occupancy. In addition, both the office/classroom and the laboratory spaces use set-backs to reduce air-flow rates during the night if a space is unoccupied as redundantly confirmed by the building control system (e.g. occupancy sensors and lights).

Natural Climate Used to Reduce Loads

The natural conditions in Incline Village provide ample opportunity to minimize building loads through climate-specific design. In fact, by designing mechanical systems to work in concert with the mild local climate and large nighttime temperature swings, the building is able to avoid using compressor-based cooling.

Cooling load reduction is first provided through nighttime flushing, fully replacing inside air with cool outside air at night. This strategy pre-cools the interior air and the building's concrete thermal mass to temper the interior temperature throughout the following day. To meet the remaining cooling load, two types of free cooling are used: water-side free cooling, which uses evaporation in a cooling tower to obtain chilled water, and air-side free cooling (economizer cycle), which brings naturally cool outside air into the building during the day. On days when the outside temperature exceeds the design point for the building, chilled water is retrieved from two 25,000 gallon storage tanks buried nearby in the ground. These tanks store chilled water produced by the cooling tower. The additional cooling capacity provided by the stored chilled water allows for the elimination of a chiller.

Two additional strategies – daylighting and natural ventilation in the offices – contribute to human comfort and the indoor environmental quality of the building. Skylights over the three-story atrium allow natural light penetration into the building's core. Lightshelves on the southern exterior, high-side lighting on all orientations, and generous interior transom glazing maximize use of daylight throughout the building interior. Energy is saved through the use of photocell-controlled dimming and switching controls, used to reduce electric light levels as appropriate throughout the day.

Prohibited in the laboratory due to pressurization and safety requirements, operable windows are provided in the office and classroom spaces. Current research (ASHRAE, Adaptive Comfort Model) suggests that operable windows and natural ventilation afford a high level of occupant comfort, without maintaining rigorous air temperature settings, when occupants are given control over their space and allowed to adopt seasonal dress. Office areas in the TCES are equipped with thermostats and manually controlled floor grilles, which utilize slider levers to control dampers, and provide more localized control for the occupants. "I believe we can achieve another 10 percent energy savings in the building as we train the building operators and discipline the building occupants to live in an energy-efficient space," says Jim Steinmann.


Photo Credit: Jeff Dow

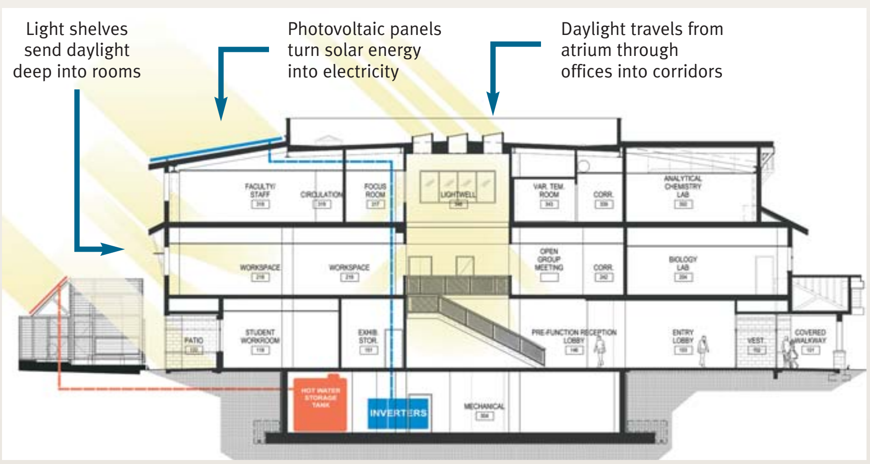


Illustration of Climate-adaptive Systems in the TCES, Courtesy of Collaborative Design Studio


Photo Credit: Vance Fox

Heating and Cooling Loads Met Efficiently

Two air-handlers for ventilation and a single hydronic heating and cooling plant serve the building. In the laboratory space, air is supplied overhead through induction diffusers. Chilled water is supplied directly to the induction diffusers to cool the air entering the space (See Sidebar: *How Chilled Beams Work*). Heating is provided via a hydronic heating coil at the outlet of VAV (variable-air-volume) boxes connected to the induction diffusers. In classroom and office spaces, displacement ventilation is used, supplying conditioned air through wall- and floor-mounted diffusers. Exhaust air in classroom and office spaces is removed through a common ducting system and staged stacks allow for effective heat recovery, resulting in smaller boiler requirements for the building as a whole.


Photo Credit: Jeff Dow

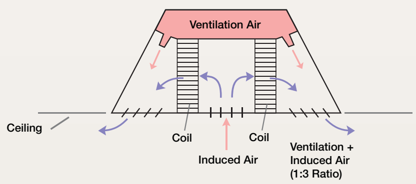
Courtesy of Collaborative Design Studio

The heating plant utilizes high efficiency (greater than 92 percent) condensing boilers and incorporates waste heat from a natural-gas cogeneration plant (see *On-site*

HOW CHILLED BEAMS WORK:

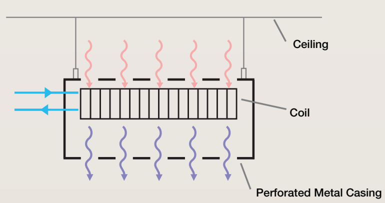
Chilled beams are sometimes called induction diffusers and use primary air flow to induce a secondary air flow.

Active:



Active chilled beams tie into the room's primary air supply ducts, mixing supply air with existing air, cooling the air with the coils, and then distributing the cool mixed air through diffusers in the ceiling.

Passive:



Passive chilled beams rely on natural convection. Warm air rises in a space, is cooled by the coils, and descends naturally without the assistance of fans.

The TCES uses active chilled beams in the laboratories.

Electricity Generation). In addition, the boilers operate at lower temperatures than typical (180°F). TCES boilers have set points that reset from 80°F to 120°F when outside air moves from 65°F to 40°F, allowing the boilers to operate at lower temperatures and higher efficiencies throughout the year. Primary heat to the building is supplied by tempering the ventilation air delivered to the spaces. Additional heat is provided as necessary to office and classroom spaces using a two-pipe radiant panel system, and to the laboratory space using a four-pipe hydronic system.

The four-pipe system permits simultaneous heating and cooling to provide precise control of individual laboratory conditions throughout the year. Direct modulation of the amount of heat or "coolth" delivered minimizes the need for reheat and provides significant savings. The office spaces use a radiant-panel two-pipe system that has a manual switch to transition the system from heating in the winter to cooling in the summer. Chilled water for both the laboratory or classroom/office spaces is cooled by evaporation occurring in the cooling tower. This free cooling is particularly efficient for the laboratories where, in order to avoid condensation overhead, the chilled beams use higher temperature water than typical for other cooling systems.

The TCES is the first laboratory in the United States to use chilled beams, even though laboratories are particularly good applications for the technology. As previously noted, the TCES design first reduces fan energy consumption by decoupling ventilation air from heating and cooling. It further reduces fan energy by using chilled beams. Since chilled beams provide conditioning using pumped chilled water, instead of blown cold air, remaining fan energy is substantially replaced with pump energy. This substitution, due to the higher heat capacity of water, greatly reduces total energy consumption over a typical arrangement.[1] In the TCES, at least 50 percent of the cooling in the laboratories is provided by the chilled beams on an annual basis.

Displacement ventilation is used in the office and classroom spaces to deliver tempered ventilation air directly to the occupants through wall and floor diffusers. This low-pressure drop, higher volume forced-air system maximizes cooling from the ventilation air and minimizes the need for supplemental cooling from the radiant panels. Since displacement ventilation uses higher temperature supply air, the building also benefits from a longer economizer or free air-side cooling cycle throughout the year.

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[1] *Chilled Beams in Labs Eliminating Reheat & Saving Energy on a Budget*
Peter Rumsey, P.E. and John Weale, P.E., American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (www.ashrae.org). ASHRAE Journal Vol. 49, Jan. 2006.

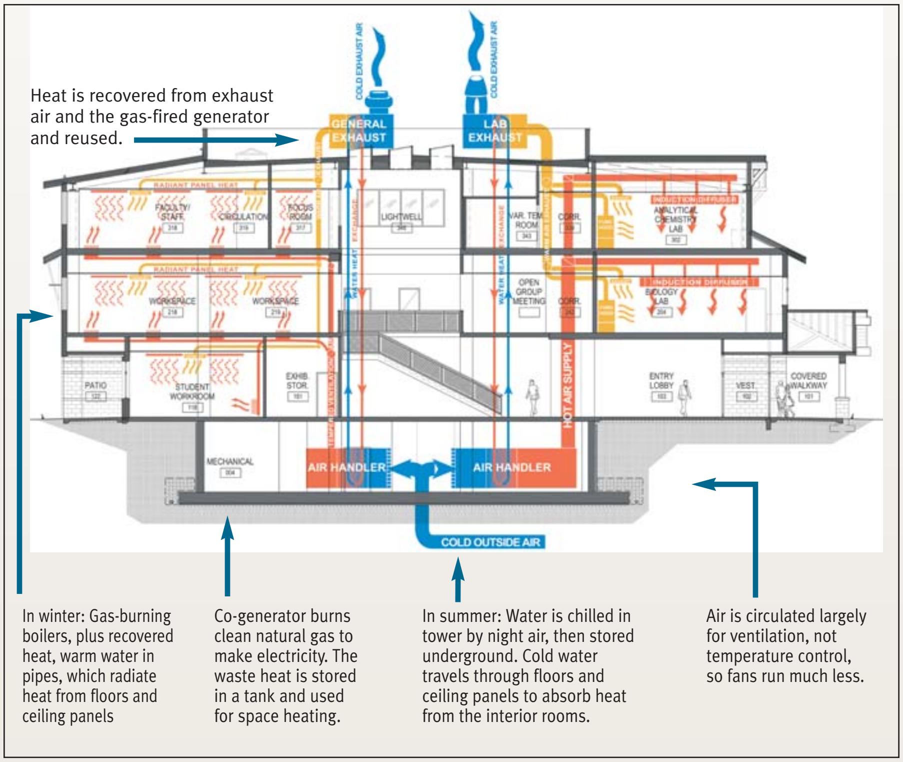


Illustration of Energy Systems in the TCES, Courtesy of Collaborative Design Studio

On-site Electricity Generation

The TCES uses two strategies to generate electricity on-site – cogeneration and solar electric. These systems increase energy efficiency and decrease building emissions. The cogeneration plant serves as an efficient and clean source of electricity and assists in the hydronic heating of the building. A turbine powered by natural gas spins to generate electricity. Exhaust heat from this process is reclaimed to help heat the water used for heating.

A second electric generation system is installed on the roof of the building: a grid-tied solar array, consisting of 875 photovoltaic shingles. The system has generated over 34,000 kilo-Watt-hours of electricity in its first year of operation or about eight percent of the building's annual electric consumption. Future projections set the solar-electric contribution even higher. Two solar hot-water panels were also installed and preheat the domestic hot water for the building. In addition to lowering operating costs throughout the year, these on-site active systems eliminate utility distribution losses further reducing emissions associated with building operation.

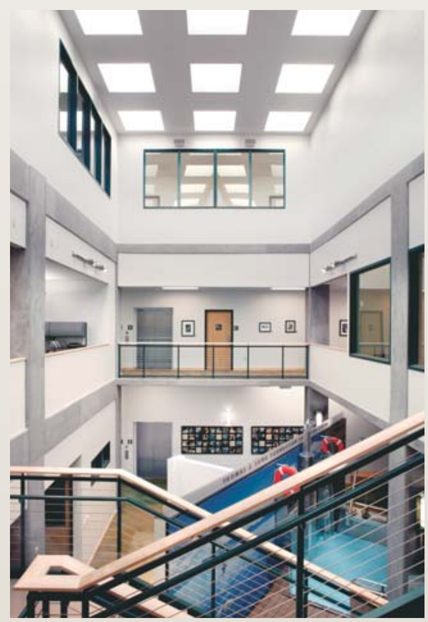


Photo Credit: Jeff Dow

Courtesy of Collaborative Design Studio

Additional Sustainable Features

Along with energy savings, water conservation was a key driver in the design of the building. "A rainwater storage system captures the rain and snow that falls all year near Lake Tahoe and uses it to flush toilets, which is particularly exciting," according to Ryan Stahlman of the Collaborative Design Studio. TCES water-saving strategies result in approximately 30 percent savings over a comparable building. The landscape design incorporates native vegetation, and only a small above-ground irrigation system that is temporary was installed. Low-flow plumbing fixtures include dual-flush water closets, waterless urinals, and low-flow kitchen sinks, lavatories, and showers.

In addition, efforts were made to use environment friendly building products whenever possible. The final design included materials such as:

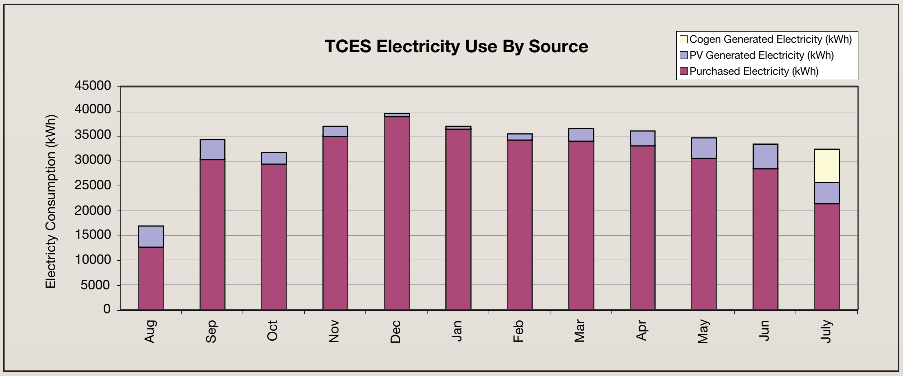
- Wood harvested and milled on-site
- Structural concrete with 25 percent fly-ash content
- Wheatboard cabinets and carpet tiles with recycled materials in classrooms and offices
- Particleboard substrate cabinetry and linoleum floors in laboratories
- Wall insulation made from recycled blue jeans

"When compared to similar labs in the Labs 21 benchmarking data base, the building uses less than one third of the energy. Substantial reductions in the measured energy savings are confirmation that creative design applied carefully can provide real savings and improved health and comfort in buildings."

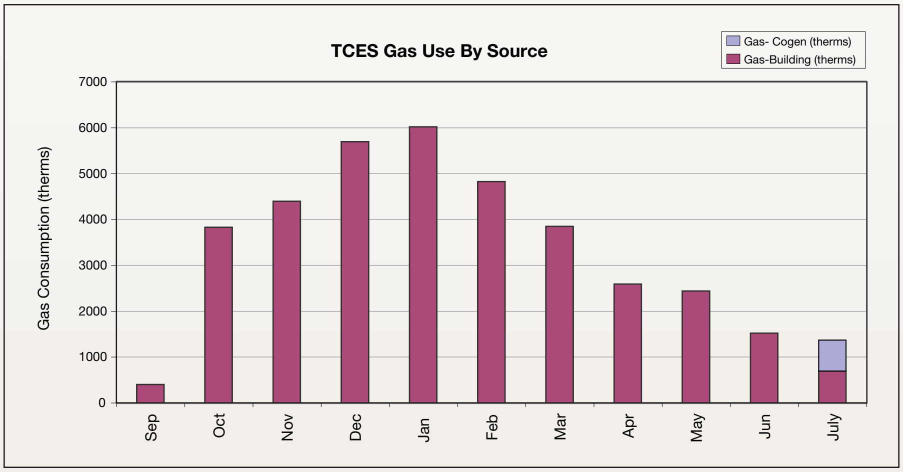
Peter Rumsey,
Mechanical Engineer

Actual Building Performance

Rumsey Engineers was able to compile energy performance results for the building's first year of operation using utility information provided by Sierra Nevada College and data from on-site monitoring. The following charts, courtesy of Rumsey Engineers, summarize electric and gas consumption by source type and energy cost savings. Minor commissioning work is on-going, and the cogeneration system was not in operation until the eleventh month of the first year. Nevertheless, actual building performance is impressive.

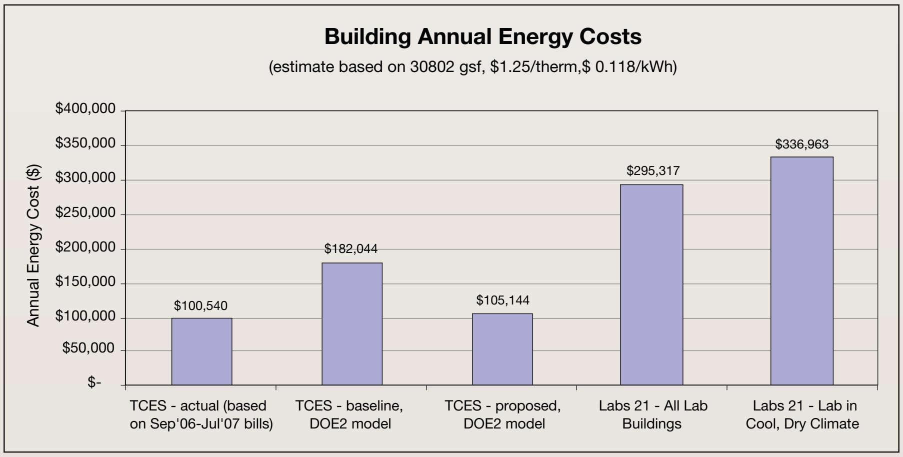


Monthly electric consumption shown in kilo-Watt-hours and by source for the TCES.



Monthly gas consumption shown in therms and by source for the TCES (August 2006 data was unavailable).

Actual energy cost savings over the first year were five percent better than predicted by the DOE-2 energy model used during design, 45 percent better than the baseline ASHRAE 90.1-compliant DOE2 model, and 70 percent better than a Labs 21 building model for a cool, dry climate.



Actual total annual energy costs compared to model estimates.

Total energy cost savings compared to a baseline ASHRAE 90.1-compliant DOE2 model will save Sierra Nevada College more than $80,000 per year. Assuming five percent annual inflation, the projections are $17 million during the next 50 years. Total energy cost savings compared to the average lab in the Labs 21 database are close to $200,000 per year. Using five percent annual inflation, the value is close to $40 million for a 50-year period.

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