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EMERGING TECHNOLOGY

Advances in building systems and materials

Putting the sun to work

Renewed interest in energy efficiency has brought solar technology back out from under a cloud

By Dan Brown, Contributing Editor

You don't have to mine it, truck it from a refinery or clean up the air when it burns. Sunlight: It's clean, free and available the year 'round.

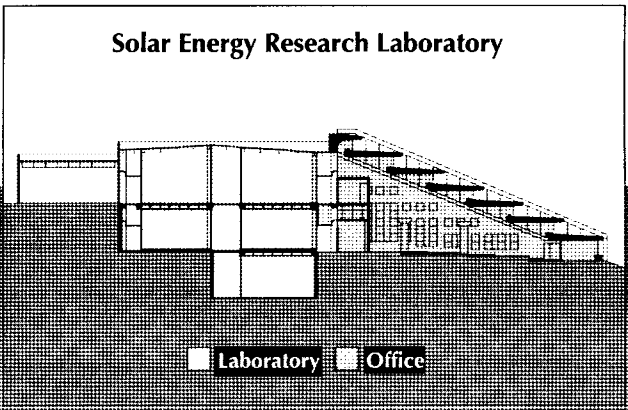
Existing solar technology could save this nation a good deal of energy. Scientists estimate that solar designs and increased energy efficiency could cut demand for energy in America's buildings by more than $50 billion per year.

During the Reagan years, solar research was cut to a fraction of its former levels, but now solar energy is rebounding. New government programs are sponsoring research for both active and passive technologies. Solar buildings are springing up across the nation; the cost of photovoltaic systems, which convert sunlight to electricity, is dropping fast. Moreover, new glass technologies are playing sunlight like a violin, controlling the amount of visible light and heat. (See accompanying story.)

National lab exploits solar techniques

The current leading example of proven solar technology and energy conservation is the Solar Energy Research Laboratory (SERL) in Golden, Colo. Built for the National Renewable Energy Laboratory (formerly the Solar Energy Research Institute), the 116,000-sq.-ft. SERL building accommodates cutting-edge research in electronics, physics, optics, lasers and superconductivity.

For $170 per square foot, architects


Solar Energy Research Laboratory

Anderson DeBartolo Pan (ADP), Tucson, designed a building expected to consume at least 30 percent less energy than the amount called for by federal standard 10CFR 435.

The building achieves its energy savings through a list of proven technologies: extensive daylighting, heat recovery from process laboratory heat, both direct and indirect evaporative cooling, variable-frequency motor drives, high-efficiency artificial light, a Trombe wall and automated shades triggered by photovoltaic cells.

So effectively does the building use daylight that offices do not need artificial light during the period from an hour after sunrise until an hour before sunset, says ADP design principal Jack DeBartolo. In effect, the large, open site parallel to the foot of a mesa created a natural longitudinal axis for the structure. Integrating the building into the toe of the mesa allows it to face 15 degrees to the east for maximum daylight.

This orientation led the architects to choose stepped light shelves to draw daylight into the building. A reflective finish on the building's roof panels bounces sunlight up from the shelves, driving it deep into open offices behind the stepped clerestories.

Daylighted spaces exude a better feeling, the experts say, if the light is distributed evenly, leaving no dark areas. So to improve distribution in the open office spaces, lighting consultant Steve Ternoey of Boulder, Colo., recommended tinted glass to graduate the amount of light admitted from 78 percent at the upper clerestory level to 38 percent at the lower level.

Because more low-angle light strikes the lower level than the higher level, it must be blocked more in order to achieve even distribution. At the upper level, which boasts a much higher floor-to-ceiling height, more light can be admitted to fill the space and reach the ceiling. "We wanted to create the metaphor of a second sky indoors," says DeBartolo.

Office windows in the east and west module walls admit only 28 percent of available light and have a low-E (emissivity) coating to cut glare and solar thermal loads. Photosensitive devices control window shades on those exposures, raising and lowering them automatically. To optimize light transmission and shading coefficients, six types of low-E glass were used in the building.

To provide the control needed for tests and research, artificial lighting is used in the labs, which are located behind the daylit offices. The labs employ a CV terminal reheat system using 100 percent outside air; offices use a VAV terminal reheat system with a wet-bulb economizer.

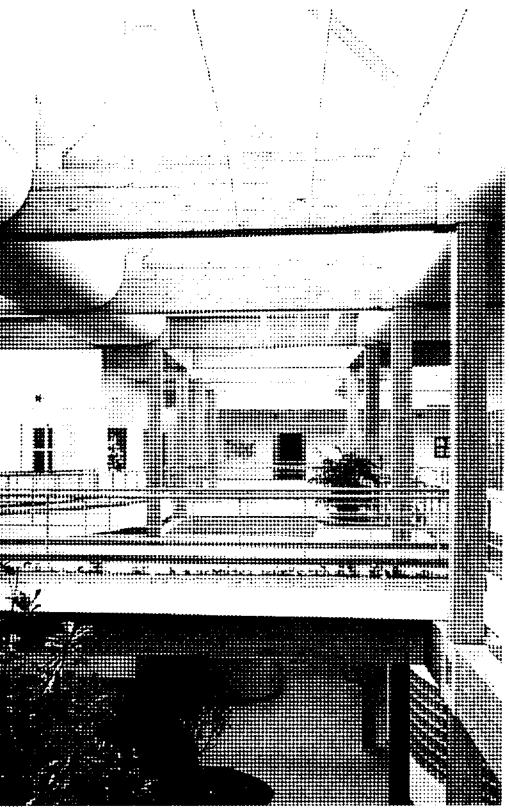
The large, high-ceilinged open office spaces — with nearly 10,000 square feet in each — presented engineers with a problem: How could they deliver ventilation air? The answer: four "air trees," or columns, each with a truncated cone on top, carry air upward through the column and deliver it through nozzles

(Opposite page) *Reflective metal panels on the Solar Energy Research Laboratory bounce sunlight upward from the stepped shelves, driving daylight through the clerestories and deep into the building's office spaces. No artificial light is required for these spaces during the period from an hour after sunrise till an hour before sunset. (Left) Ventilation is supplied to the the high-ceilinged offices with "air trees," columns that carry air upward through the base and deliver it through six nozzles aimed at the cubicles. Each air tree contains a VAV box, distribution duct and "elephant trunks" leading out to the nozzles.* Photos: Bob Harr, Hedrich-Blessing

Photovoltaic systems can be incorporated into windows, skylights, roofing materials and shading materials

aimed at the cubicles. Each air tree contains a VAV box, distribution duct and "elephant trunks" leading out to six nozzles.

To sell the owner on the air tree concept, a quarter-scale model, through which smoke was blown, was made by Will Brown, ADP's project mechanical engineer. Lab personnel who conduct studies on cold air distribution assisted in the test by supplying infrared photography equipment, which provides a real-time display of the air-temperature gradients in a room. The test revealed no large thermal gradients.



A light court (above) *at the Way Station, a 30,000-sq.-ft. health facility, admits daylight into circulation areas and surrounding offices. Light banners prevent direct glare and guide light downward; curved soffits maximize light intake. Other solar techniques at the Way Station include a south-facing light shelf and a daylight tracking system (right).*

School earns an "A" for daylighting

Another prime example of daylighting's ability to save energy comes from the Four Oaks Elementary School in Johnston County, N.C. The $6.4 million building, designed by Alicia Ravetto and Gary Bailey of Innovative Design Inc., Raleigh, N.C., cost just $55.02 per square foot in 1991.

In its first year of operation (through April 1992), the building used 36,410 BTU/square foot. By contrast, a comparable North Carolina school consumes nearly double that — 72,600 BTU/square foot/year. On an annual basis, the operating cost of Four Oaks has been $0.52/square foot, compared to about $0.88/square foot at the comparable school. Annual savings: $37,000 per year for this school of about 103,000 square feet.

To maximize exposure to the sun, Four Oaks is aligned with its longest dimension running east-west. Key elements in achieving effective daylighting are vertically glazed roof monitors. They admit low-angle sun for lighting and heating, but exclude direct solar gain when the summer sun is higher in the sky.

Daylight streams directly into the monitors, striking a set of translucent fabric baffles set inside monitor cavities to block direct sun glare. "We made the baffles translucent so that you don't see the contrast between light and dark in the room," says Michael Nicklas, president of Innovative Design.

The monitor cavities form ceiling openings that are "pulled in from the walls about six to eight feet," says Nicklas. "If we didn't need as much light in some places, we could pull in the ceiling openings a little more." Low-E glass was used on the south-facing and north-facing window areas. The monitors have clear insulating glass.

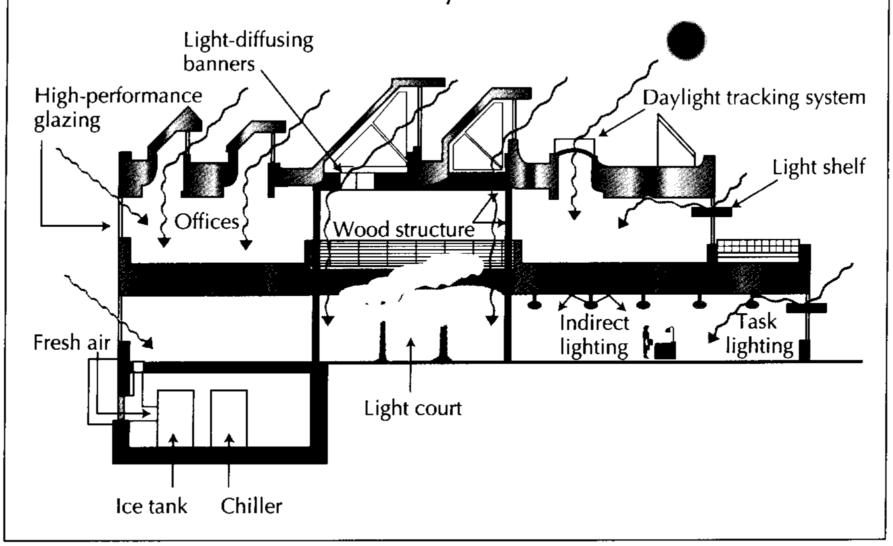
Experience gained at Four Oaks enabled Innovative Design to enhance solar architecture at two other Johnston County schools completed last year, one in Clayton, the other in Selma. The Clayton school cost $7.7 million and Selma cost $6.9 million. Estimated annual energy use in the two schools is 24,395 BTU/square foot, resulting in an annual energy cost of $0.48/square foot — exceeding even Four Oaks' performance. Architects Ravetto and Bailey estimate that south-facing roof monitors at the two middle schools will pay for themselves in nine to 11 years, depending on whether calculations assume a nine-month or a 12-month school year.

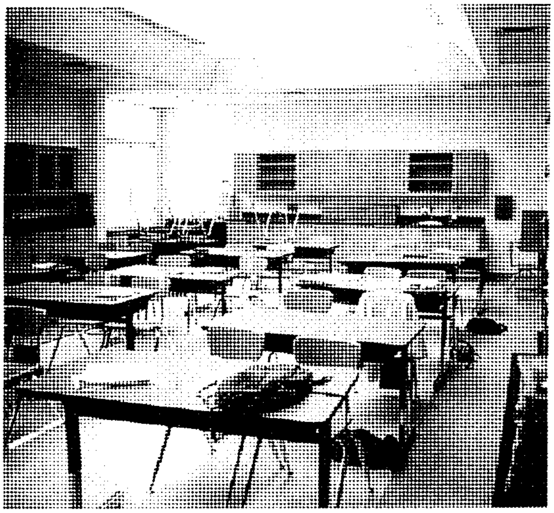
Changes from the Four Oaks design include roof monitors with higher percentages of glass area and improved light wells above classrooms. At the bottoms of the light wells, ceiling openings flare down and outward at a 45-degree angle, cutting off corners that would block daylight, says Nicklas. The result: Both the amount and distribution of daylight is much improved.

Health center optimizes light court

Like the North Carolina schools, the Way Station, a mental health center in Frederic, Md., employs south-facing light monitors to draw daylight into the

The Way Station





***Rooftop monitors admit daylight** into each classroom of this school in Johnston County, N.C. To distribute daylight to the room's edges, the monitor's walls are flared and the exterior windows are placed near the corners of the room.* Photos: Innovative Design Inc.

building. The $5.5 million building was designed by Gregory Franta of Boulder, Colo.-based ENSAR Group.

A light court at the building's core admits daylight into circulation areas as well as into the surrounding offices. On the south side, light shelves permit daylight to penetrate deep into the building, yet shade brightness near the window and block unwanted solar heat gain. Three daylight tracking systems, which use photovoltaic cells to control light reflectors that track the sun, assure maximum daylight levels on the second story.

Photovoltaics research regains momentum

When President Reagan was elected in 1980, federal funding for photovoltaics (PV) was slashed by a factor of four, says president Steven J. Strong of Solar Design Associates. Remaining funds were restricted to "long-term, high-risk" projects rather than those that might yield near-term results.

With that change, a number of U.S. manufacturers either dropped out of the PV development race or reduced their involvement. World leader ARCO Solar sold its technology, plant and equipment for a fraction of its worth; Exxon, Texaco, Shell, General Electric, Westinghouse, Boeing and Martin Marietta drastically cut back solar programs.

Now, research by utility PV experts shows that distributed programs — with solar PV systems mounted on building roofs or facades — are much more likely to "achieve early market penetration than are large central station applications," says Strong.

In 1985 the New England Electric System placed 100 kw of distributed, rooftop systems, including the world's first PV-powered neighborhood, in Gardner, Mass. And now utilities such as the Sacramento Municipal Utility District (SMUD) — following the failure of the Rancho Seco nuclear powerplant — are beginning to install PV systems to support their grid.

In addition to fielding residential rooftop PV systems, SMUD is integrating PV systems into commercial buildings. A multiyear program placed some 640 kw of distributed PV systems last year, and will place 1.5 mw this year, followed by 2.3 mw in 1995. Technology exists for PV structures to act as windows, roofing material, skylights or shading material, SMUD officials say.

Nevertheless, Strong believes that the U.S. lags behind Japan and Europe in building-integrated PV technology. If the Japanese get too far ahead, their exports of PV technology and equipment will represent yet another loss in the U.S. trade battle with Japan, Strong says. □

Argon + low-E = R-4

"A number of successes in daylighting these days are being driven by products and materials that were not available five or ten years ago," says solar expert Harry Gordon, principal at Burt Hill Kosar & Rittelmann Associates' Washington, D.C., office.

A central player in this progress is glass and glazing systems. Modern glass technology enables architects to control glazing's U-value, its shading coefficient and its visible light transmission. Low-E (emissivity) coatings enable glazing systems to reflect heat inward in the winter and bounce it away in the summer to minimize heating and cooling loads. Low-E glass reflects infrared heat, passes visible and near-infrared solar energy, and blocks a large portion of UV rays.

Although windows of low-E glass reflect 60 percent of radiant heat, they still transfer some heat due to conduction and convection of the dessicated air between the panes, says research associate Peter Gerhardinger of Libbey-Owens-Ford Co., a major glass supplier based in Toledo, Ohio. The answer: Construct insulating glass using argon or krypton as a filler between the panes.

A readily available and inexpensive noble gas, argon can stop much of the remaining heat transfer through insulated glazing. The following U-values are for insulated glazings with and without argon and low-E coatings:

Standard double pane
with air insulation: 0.49
Standard double pane
with argon insulation: 0.46
Air insulation and low-E:
0.30-0.35
Argon insulation and low-E:
0.26-0.30.

Glazing with a U-value of 0.26 translates roughly to an R-4 insulating glass.

Argon enjoys one advantage over krypton, says Gerhardinger; it's much more abundant. Many customers, once they pay the extra for low-E glass, go all the way to maximum insulating value with argon. In fact, market penetration of low-E glass now approaches 40 percent in the residential market and 27 to 29 percent in commercial buildings. □