The Rio Grande Conservatory

A botanical conservatory in New Mexico illustrates the versatility of window glazing technology for 21st century building design.

by Paul Kriescher and Ed Mazria

Courtesy of Design Workshop

The all-glass Rio Grande Conservatory in Albuquerque, New Mexico, consistently sustains temperatures 20 to 30°F (12 to 17°C) above outdoor lows.

Humans have sought shelter since they first walked on the Earth. For just as long, they have worked to make their shelters more comfortable and convenient. The architectural culture of the Western world has addressed this desire for comfort and convenience through a philosophy of defense against the perils of nature. This defense is obvious in humans' use of heating and air-conditioning equipment that isolates a building's occupants from the outside environment. It is an approach that has allowed individuals to control the interior built environment, but has also caused many architects to forget that not all of the outside environment needs to be defended against.

Today, as public concern mounts about the environmental damage caused by conventional energy technologies, architects are exploring new methods of providing energy to buildings so that they have a more cooperative relationship with the environment. Human architectural history is full of examples of this building design philosophy—the passive solar dwellings of the Pueblo people of the southwest U.S. and Japanese Shoin architecture of the 16th century that used shoji sliding screens for natural ventilation are two examples.

Courtesy of Design Workshop

The 2700 square foot (251 m²) Desert Pavilion houses over 900 species of plants from the Chihuahuan and Sonora Deserts as well as the Baja California area.

Modern examples of this building philosophy make use of solar energy through active and passive solar heating, natural ventilation and daylighting. Window glazing is always a key element in creating successful modern solar buildings.

The technology choices now available in glazing make it possible to maximize the use of the sun's energy while minimizing the heat loss and gain associated with large expanses of glazing. Mazria Riskin Odems Inc., the architects of the Rio Grande Conservatory, an all-glass botanical conservatory in Albuquerque, New Mexico, created a striking example of what is possible through the judicious use of modern glazing technologies.

Sophisticated Glazing

As the Conservatory demonstrates, glazing serves three purposes in a building. First, it allows light and heat into the building interior and allows occupants views out of the building. Second, it serves as an insulating/ weatherization barrier for the building. Third, operable window glazing provides natural ventilation.

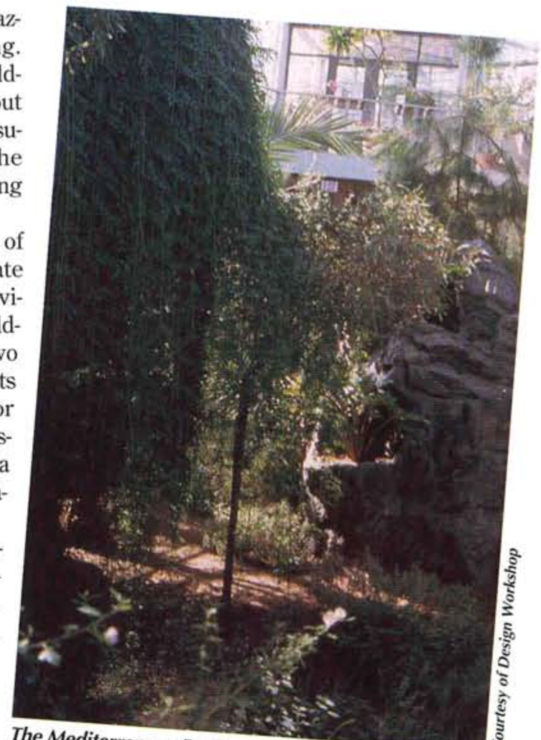
For the architects and occupants of energy-efficient buildings that relate cooperatively with the outside environment, glazing is key to the building's energy balance. In the last two decades, technological improvements in glazing have made it possible for architects to choose highly sophisticated glazing materials to fulfill a specific function in a specific location.

Technological glazing improvements include tinting, suspended plastic films, low-e coatings and special products (e.g., gas-fills and thermally improved glazing spacers). Tinting, a defensive strategy and one of the first technological improvements made to commercial, and, less frequently, to residential glazing, reduces the total amount of solar radiation passing through the glass in order to minimize heat gain.

Increasing Insulation Values

Adding a second pane of glass to a window's glazing increases the insulation value by nearly 100 percent. Adding a third pane of glazing further increases the insulating properties of the glazing. Triple-pane glazing in a window with a wood frame, air-filled and aluminum spacers increases the insulation value 45 percent over double-pane glazing. However, the added cost and increased weight and decreased visible and solar transmittance reduces the benefits of adding more panes of glazing.

In response to the diminishing effect of adding panes of glass, some glazing manufacturers began installing an inner plastic film in place of the middle layer of glass. The film adds insulating value roughly equivalent to another pane of glass, but is very thin and lightweight, and doesn't add weight or width to the unit. Because the plastic film is opaque to ultraviolet (UV) radiation, this glazing has the additional benefit of blocking damaging UV light. In "Heat Mirror" windows, a low-e coating is deposited on this plastic film, further increasing its insulating value.



Courtesy of Design Workshop

The Mediterranean Pavilion encloses over 7000 square feet (650 m²) of space devoted to plants native to a Mediterranean climate such as southern California, coastal South Africa, Australia and Chile and the Mediterranean basin.

High-Tech Design

By using different types of glazing in different parts of the building, the Conservatory's architects created two unique interior environments. The 10,000 square foot (929 m²) building comprises two pavilions, each covered by a selective mix of advanced technology glazing. The 2700 square foot (251 m²) Desert Pavilion houses over 900 species of plants from the Chihuahuan and Sonoran Deserts as well as the Baja California area. The Mediterranean Pavilion encloses over 7000 square feet

(650 m²) of space devoted to plants native to a Mediterranean climate such as southern California, coastal South Africa, Australia and Chile and, of course, the Mediterranean basin.

Each pavilion is conceived as an open system, characterized by a continuous exchange of energy and matter with the environment in order to maintain internal conditions suitable to its particular resident plant life. The building skin of window glazing, vents, masonry and insulation filter the environmental elements needed to sustain the system and to create specific conditions for healthy plant growth, with little or no imported energy.

Sunlight enters each pavilion from all directions through the glazed roof and walls. This is important to recreate the diffuse sky to keep plants from growing towards a singular diffuse light source. Each pavilion, and each area of the pavilion, depending on orientation and pitch, has specific solar transmission and thermal properties. The architects selected the glazing for its ability to transmit the part of the solar spectrum that plants need most for photosynthesis—the blue (450nm), red (660nm) and far-red (750nm) wavelengths.

A computer simulation model using energy analysis software determined the specific properties of building elements—the envelope to filter and regulate the exchange of energy and matter with the environment; the concrete walls and floor, metal structure, soil, water and plants to absorb, convert, store and release energy for system stability; and the location, size and openings for natural and induced ventilation. The simulation was used to assess the impacts of changing variables in the design, including glazing, building materials, size and location of openings and the rate of air and heat exchange with the outside environment at different times of the year. The computer simulation influenced designers to select specific glazing for the Conservatory depending on the its angle and exposure to the sun.

The design of each pavilion was fine-tuned using computer simulations so that the relationships among system components produced dynamic internal environments that closely resemble those of the Sonoran Desert and the Mediterranean Basin climates. The designs resulted in pavilions that are virtually self-sustaining climate reproductions—with the exception of water needed by the plants.

The arid, high sierra climate of Albuquerque with its 4389 Heating Degree Days (HDD) and 1310 Cooling Degree Days (CDD) more closely resembles the Sonoran Desert than Mediterranean Basin, but still experiences colder temperatures than either area. In order to account for severe and atypical weather conditions, the building features hot water baseboard heating, fan induced ventilation and, in the Mediterranean Basin, a fogger system. The boiler for the space heating is 1/10th the size required by a conventional building of comparable size. The 80,000 Btu input unit only runs a few hours each evening in December through February. The building performs so well that the backup is used only to ensure that the temperature in the Mediterranean Pavilion stays above 40°F (5°C).

Courtesy of Design Workshop

Strategically placed vents encourage natural ventilation at the Conservatory.

Exemplary Performance

The Conservatory has been open to the public and monitored for over two years. A close examination of its performance during this period reveals that each pavilion exhibits the remarkably high degree of internal thermal order that is characteristic of living systems. Through the ceaseless exchange of energy and matter with the environment, each pavilion is able to renew and maintain itself in a dynamic state that is very stable over time.

Monitoring data show that both pavilions continuously sustain temperatures that are 20 to 30°F (12 to 17°C) above the outdoor lows. Daily temperature fluctuations are consistent within a narrow range of 15 to 20°F (9 to 12°C) in both summer and winter, and when the annual temperature profile of each pavilion is matched against that of a Sonoran Desert (Tucson, Arizona) and Mediterranean Basin (Los Angeles, California) climate, their profiles are strikingly similar. If, by design, we can create desirable indoor conditions in a conservatory with little or no imported energy, it should come as no surprise that we can create similar low-energy environments in other building types, including housing, educational and recreational facilities, commercial buildings and libraries.

A Choice for Every Building

Lessons learned from the Rio Grande Conservatory project demonstrate the importance of glazing selection, as well as the significance of thermal mass in stabilizing temperatures in this type of space. These lessons can be applied to unconditioned transitional spaces—vestibules and atria, for example—in other buildings.

In designing buildings that conserve more of our natural resources, glazing performance will play an increasingly important role in capturing the sun's energy for daylighting and space heating. And as designers seek to understand the synergistic relationships between glazing technologies and other features of the building envelope and heating and cooling systems, computer modeling becomes increasingly necessary.

As the architects of the Rio Grande Conservatory found, using an hourly computer simulation tool makes it possible to predict performance and refine a building's design before it is built—a far more cost-effective strategy than collecting performance data once the building is occupied. Technological advances in glazing and increasingly sophisticated computer models allow today's designers to create buildings that are easy on the environment while offering occupants 21st century comfort and convenience. ✪

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This is one in a series of articles of SOLAR TODAY articles describing successful sustainable-energy buildings throughout the U.S. The first eighteen articles are available as full color book from the American Solar Energy Society. The series is part of the Buildings for a Sustainable America education campaign (BSA). The BSA education campaign is sponsored the American Solar Energy Society, the Sustainable Building Industries Council, the National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy Office of Building Technology, State and Community Programs. Work is currently underway by DOE and NREL to provide designers with improved technologies and design tools to use in producing cost-effective, high performance buildings.

Rio Grande Conservatory Project Details

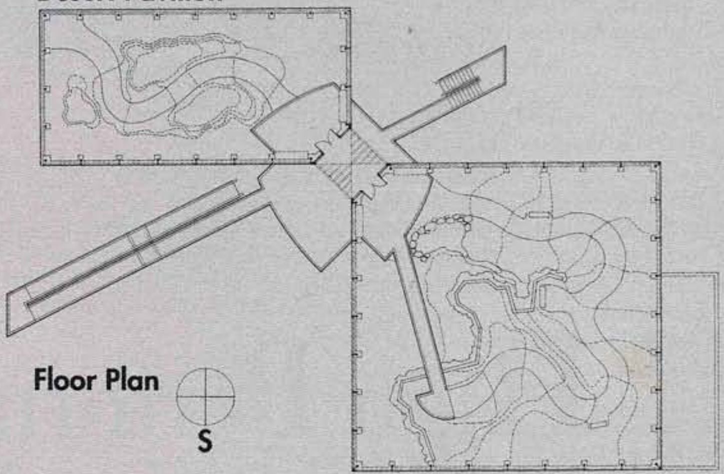
Project Description: The Rio Grande Conservatory Botanical Garden, including Sonoran Desert and the Mediterranean pavilions.
Architect: Mazria Riskin Odems Inc. Santa Fe, New Mexico, Ed Mazria, Architect, Principal-In-Charge. Joseph Chipman, Project Architect
Landscape Architect: Design Workshop, Albuquerque, New Mexico
Size: 10,000 square feet. 2700 square feet of Sonoran Desert. 7300 square feet of Mediterranean Basin
Year Completed: 1998
Construction Cost: $1,580,000- $158/ square foot (1998 dollars)
Location: Albuquerque Biological Park, Albuquerque, New Mexico
Heating Degree Days: 4839
Cooling Degree Days: 1310

DESIGN FEATURES

- Open system maintains a continuous flow and exchange of energy and matter with the environment.
- Architects used computer energy simulations to select glazings for their transmission of solar radiation (heat and light) most needed by plants for photosynthesis.
- Supplemental space heating unit is 1/10th size of boiler needed for a typical building of this size.
- A ventilation system with low intake vents and high exhaust vents for cooling of the facility.
- A fogger added to the Mediterranean Basin pavilion for added moisture levels not naturally present in the Albuquerque climate
- Maintenance-free aluminum space frame structure

BUILDING PERFORMANCE

- The building's open system performance is proving true after the first year. Daily temperature fluctuations are consistently within a narrow range of 15-20°F (9-12°C)
- Temperature profiles of the Sonoran Desert pavilion are within 5°F (3°C)—either high or low—of the Sonoran Desert climate of Tuscon, Arizona.
- Temperature profiles of the Mediterranean Basin pavilion are within 2-3°F (1-2°C)—either high or low—of the Mediterranean Basin climate of Los Angeles, California



NREL's Paul Torcellini and Ron Judkoff, and Dennis Clough of the Department of Energy (DOE) provide technical oversight for these articles. Work is currently underway in the DOE and NREL to provide designers with improved technologies and design tools to use in producing cost-effective, high performance buildings.

The Buildings for a Sustainable America (BSA) is a nationwide effort to make policy makers, building professionals and consumers more aware of the benefits of applying sustainable energy principles to building design and construction, These benefits include increased affordability, more jobs, improved health, reduced energy consumption and less environmental impact.

Energy

The building's Open System approach, including passive solar heating, natural daylighting and mechanical and natural ventilation systems, result in energy consumption levels that are only 5-10 percent of a comparable facility.

Affordability

The building's mechanical systems were only 15 percent ($237,000) of the total construction budget. In a conventionally designed conservatory, the mechanical system budgets can take up 35-45 percent of the total budget.

Jobs and Economy

Dollars not spent on energy are expended elsewhere in the state economy, helping to create more jobs than if the same dollars were spent on conventional energy supply.

Environment

The energy savings from the design of this conservatory means that there is only 1/10th the air pollutants of NO_x, SO_x, and CO_2 associated with a conventional Conservatory that uses natural gas for space heating and coal generated electricity for other energy uses.

Conservatory Glazing (All glazing is double pane)

Direction	U-value	Visible (VT)	Shading (SC)	Solar Transmittance
Vertical Glazing in Mediterranean Pavilion, Vertical & Sloped Glazing in Desert Pavilion	0.29	0.60	0.42	24-31%
Sloped Glazing in Mediterranean Pavilion	0.29	0.42	0.33	19-23%
Lower Windows & Glass Doors	0.33	0.75	0.65	40-45%