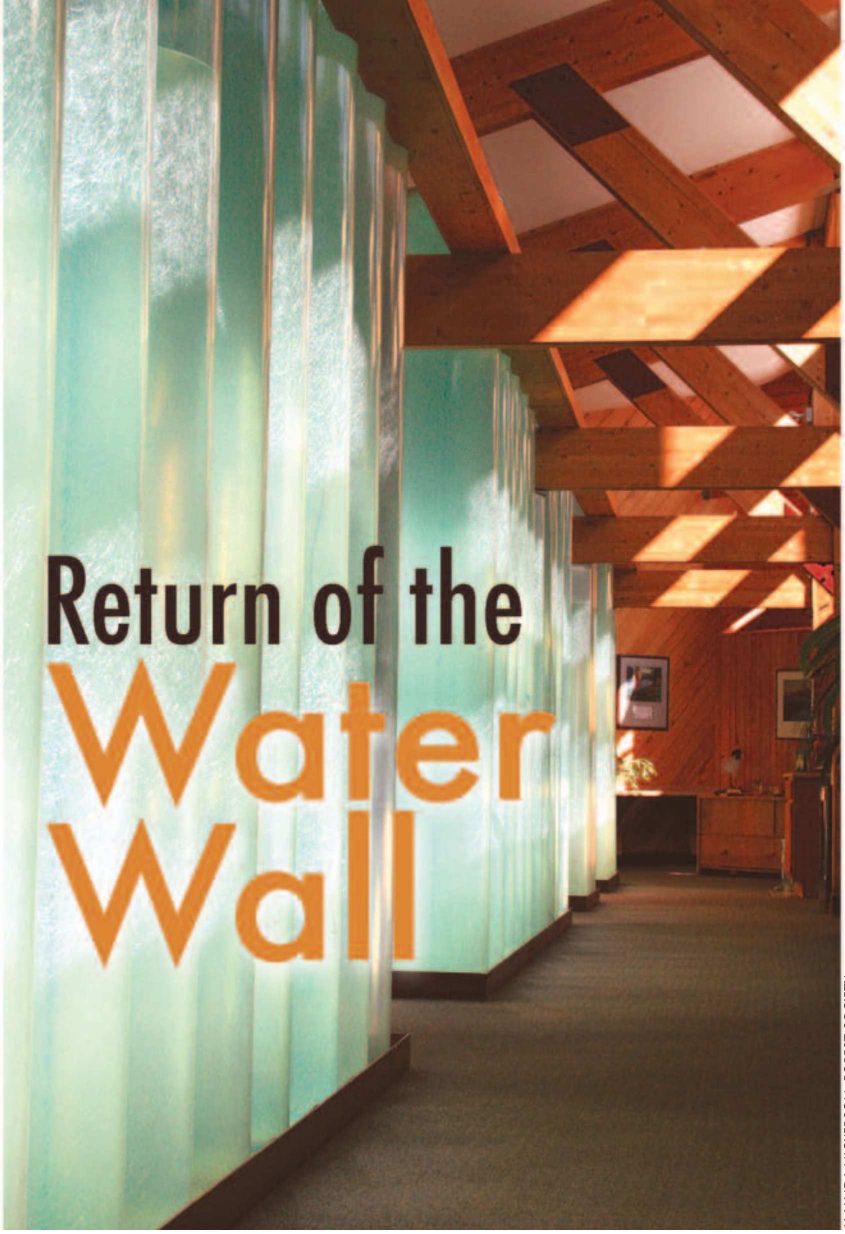
Return of the Water Wall



AMANDA NICKERSON, FOREST SOCIETY

This proven passive solar design technology has the power to quench rising energy demand in homes and other buildings.

By David A. Bainbridge, Ken Haggard and Polly Cooper

Growing concerns about global warming and rising energy prices worldwide once again are encouraging architectural designers, builders, homeowners and regulators to consider sustainable energy sources and energy-efficient heating and cooling. The most economical solution for most buildings and climates is passive solar design — using environmentally responsive building design to collect and store solar energy for heating in winter and using climate-responsive resources for natural cooling in the summer. These buildings offer improved comfort with stable radiant temperatures, reliability and low-cost energy. One of the most effective solar solutions is the use of water walls in passive solar buildings.

Passive solar design relies on the sun's energy, rather than mechanical equipment, to keep living spaces comfortable. Key elements are super-insulation (R-30-plus walls, R-40-plus attic), high-quality windows and doors, good orientation, effective cross and stack ventilation, and thermal mass. Water, with more rapid heat exchange than concrete or masonry, can be more effective in providing thermal mass for passive buildings, offering a 10 percent to 20 percent advantage over a slightly larger masonry wall in moderate climates. It is reasonable to expect energy savings of 70 percent to 90 percent for heating and cooling over the year.

Because water walls exchange heat more readily, they can be smaller than an equivalent-performance masonry wall. That allows better viewscapes, avoiding the claustrophobic sensation possible with full masonry walls. The smaller size of water walls

New Building Displays Established Technology

Congregation Beth David
San Luis Obispo, Calif.

- 16,000-square-foot (1,486-square-meter) facility is passively conditioned with no central HVAC system.
- 92 linear feet (28 linear meters) of tanks containing 65 tons (59 metric tons) of water provide about 4 million BTU on a typical day.
- Glazed water walls are placed beneath and behind windows on the south façade.
- 38.3 percent energy saving over California's Title 24 efficiency requirements.
- Building cost $155 per square foot.
- Completed December 2006.
- Designed by San Luis Sustainability Group, www.slosustainability.com.

SAN LUIS SUSTAINABILITY GROUP

Facing page, in the 1970s engineers at the firm now known as Solar Components developed fiberglass tubes for water storage. For nearly 30 years, these tubes have performed well in installations such as the office of the Society for the Protection of New Hampshire Forests. Above, The San Luis Sustainability Group's architects like to use water wall tanks beneath south-facing windows, effectively combining direct and indirect heat gain in a passive approach to heating.

also makes it easier to add movable insulation for better performance in severe winter climates.

Water walls can be attractively accented or practically invisible, as desired. Water walls are most easily incorporated in new construction, but they can also be retrofitted economically in many existing buildings. And as with all mass systems, buildings with water walls are extremely comfortable because of the large radiant surface.

The term "water wall" refers not only to actual water walls, the most common application, but also to the use of water containers in other configurations. "Water walls," in effect, is shorthand for "the use of water as thermal mass in passive solar buildings." They are particularly well suited for climates with a high diurnal swing between hot days and cool nights in the summer and mild winters with sunny days during the winter.

The performance of water wall buildings has been excellent, and modeling suggests that well-insulated water wall buildings will be comfortable and cost effective in a range of climates. Compared to a conventional home oriented without concern for the sun, a water wall building's energy savings for heating and cooling might range from 50 percent to 70 percent. With super-insulation and more control over ventilation, performance often can be increased to 70 percent to 100 percent (see, for example, Haggard et al., 2000 — details in "Resources" sidebar, page 41). Excellent performance can be achieved with water walls in most areas of the Sun Belt, which is experiencing rapid growth.

The cost of upgrading to passive solar can be relatively small, as well. In some cases full passive solar design saves money over conventional design because mechanical HVAC equipment can be downsized or eliminated. Our rule of thumb is that a 50 percent reduction in energy use can typically be realized through changes

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DAVID A. BAINBRIDGE

Three model configurations have emerged: Low water wall tanks (shown primed and ready to install); large wall-height tanks, like this one shown with a complementary wood stove at the Village Homes development in Davis, Calif.; and a counter-height water wall at the office of San Luis Sustainability Group (author Ken Haggard is shown).

at no additional cost, and a 90 percent reduction in energy use might add 10 percent to the construction cost. Actual savings will depend on the site, climate and building goals, of course.

The use of a well-oriented, super-insulated shell (straw-bale construction often will be the most economical choice) with a water wall would boost performance significantly. In many areas of the country, no central backup heating or cooling would be required (similar to current German passive house goals). That makes life much easier when ice storms like those experienced in January cut off electricity to tens of thousands of people. In a good passive solar building utilizing water walls, comfort can be maintained without fossil fuel-reliant heating and cooling.

The addition of a roof pond or cool pool might push cooling performance to 90 to 100 percent, even in the hottest U.S. climates. Modeling suggests that even in the hot-humid climate of Tampa, Fla., or the hot-dry climate of El Centro, Calif., cooling loads could be virtually eliminated for a super-insulated passive building.

Experience Demonstrates High Performance

Far from a new technology, water walls have been refined and proven over the past 60 years. The first water wall was built at the Massachusetts Institute of Technology in 1947 by Hoyt Hottel and his students. Their water wall used a full-height array of 1- and 5-gallon (4- and 19-liter) cans, painted black and set behind double-pane glass. The test facility was divided into seven cubicles to test different configurations. These water walls provided 38 percent to 48 percent of the heating demand. Poor design — including limited direct gain through windows, inadequate curtains between the water wall and window glass, inadequate insulation (a problem until the use of super-insulation developed in the 1980s and the emergence of straw-bale building in the 1990s) and the separation of the water mass from the room by curtains —reduced the performance of this promising but suboptimal configuration. Despite good performance for the cost with these experiments, the lure of new technology caused the investigators to turn their focus to costly, often unreliable, active solar energy systems.

Water walls reemerged in the 1970s with work by solar designer Steve Baer and others. Baer's Corrales, N.M., house used stacked 55-gallon (208-liter) drums full of water to provide thermal mass for an innovative passive solar design. The system worked well, and he used similar water walls in a range of residential and commercial projects.

Baer's work influenced many people, including designer Jon Hammond, who did an excellent water wall retrofit and a new solar office building using a culvert water wall on his farm near Winters, Calif., in 1974–75. Marshall Hunt and Virginia Thigpen put in a large culvert-wall home in Davis, Calif., that still works well after almost 30 years. The cost of solar energy delivered by this elegant system has been exceptionally low.

Solar pioneer Tod Neubauer helped with the engineering development and design of water walls. David Bainbridge fell in love with water walls while working with Hammond, and used the first custom steel-tank water wall. These were installed in a number of homes in a range of configurations, with tanks built by Denny Long. Ken Haggard and Polly Cooper, at San Luis Sustainability Group in Santa Margarita, Calif., have used steel-tank water walls for more than 25 years in hundreds of homes. Performance of these water walls has been excellent.

Engineers at the Kalwall Corp. (now Solar Components Corp.: www.solar-components.com) also realized the potential of water wall solar buildings. Using Kalwall's fiberglass technology, they developed translucent cylinders for water storage. These tubes have been used in many solar buildings since their development. The office of the Society for the Protection of New Hampshire

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Forests, for instance, is still performing beautifully after almost 30 years (see image, page 38).

Over years of refining configuration designs, fabrications and installations, three models emerged for general use: a low water wall that, with a cushion on top, could be used as a seat; a counter-height tank; and a massive wall-height tank for mega-thermal mass (see images facing page).

Mike and Judy Corbett, builders of the famous 220-unit solar project called Village Homes in Davis, Calif., did much to popularize water walls. Here designer John Hofacre and others elsewhere pushed the envelope with effective large water walls using thousands of gallons of water. This configuration is often backed up with a wood stove, as shown in the photo on facing page.

Various other water wall modular systems were developed and patented, but with falling energy prices and a growing disregard for the environment in the 1980s, none was commercially successful. Tubes from Solar Components remained the only option. Many opportunities exist for new modular water walls. New low-cost water wall systems for greenhouses suggest what can be done for farm buildings and commercial and industrial facilities. For example, Polymax water wall bags (available from www.growerssupply.com) provide low-cost storage of large volumes of water for passive solar applications.

The San Luis Sustainability Group has used water walls in various passive solar buildings, including its own architectural offices, since the late 1970s. Modeling has shown that for the Central West Coast climate, the optimal thickness for a custom steel tank is 9 inches (23 centimeters). SLSG likes to use the tanks beneath south-facing windows, effectively combining direct and indirect heat gain in a passive approach to heating. The firm has done hundreds of buildings with water walls over 25 years, without a single callback regarding leaks or corrosion.

Resources for More Information

Haggard, K., P. Cooper, J. Rennick and P. Niles. "Natural Conditioning of Buildings," pp. 37-69. *Alternative Construction: Contemporary Natural Building Materials*. L. Elizabeth and C. Adams, eds. John Wiley and Sons, 2000.

Balcomb, D., et al. *Passive Solar Design Handbook, Vol. III. Passive Solar Design Analysis and Supplement.* American Solar Energy Society: www.ases.org, 1983.

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Corbett, J., D. A. Bainbridge and J. Hofacre. *Village Homes' Solar House Designs.* Rodale Press, 1979.

Mazria, E. "Water as Thermal Mass," pp. 144–186. *The Passive Solar Energy Book.* Rodale Press, 1979.

Bainbridge, D. A. "Moved in Mass," pp. 436-449. *Solarizing Your Present Home.* J. Carter, Ed. Rodale Press, 1981.

Bainbridge, D. A. "Build a Water Wall Solar Home," *Mother Earth News*, Nov./Dec. 1984, pp. 114-116.

One of SLSG's latest water wall installations is a new synagogue in San Luis Obispo, Calif. This 16,000-square-foot (1,486-square-meter) facility is passively conditioned, with no central HVAC system (see photo on page 39). A large component of this passive system is 14 water walls (92 linear feet of tanks containing 65 tons of water), which provide about 4 million BTUs on a typical heating day. The dark elements seen beneath the windows on the south façade and from the inside (photo on page 39) are glazed water walls. The building exceeded California's Title 24 energy-efficiency standards by 38.3 percent, according to an energy audit.

Despite its excellent performance, the building cost no more to build than a similar-sized building. SLSG saved more than $100,000 by eliminating the need for a central HVAC system.

Modeling Advances Make Most of Water Walls

The use of water walls has come a long way since they were first integrated into passive solar designs. Improved modeling software and a better understanding of building performance now make it possible to calculate the amount of mass you will need for effective heating and cooling after developing the floor plan, estimating the window area and deciding on construction materials and insulation levels. These predictions are good for heating and getting better for cooling. Although modeling is best to size thermal mass, as a general rule it is desirable to have 25–50 BTU of storage per square foot of south glazing.

Solar heating with water walls is easy almost everywhere with good orientation and insulation, but cooling requires careful development to capture breezes and ensure good night ventilation. Culvert walls and other dispersed water wall mass systems will provide more effective heat transfer for night-ventilation cooling. Whole-house exhaust fans can be used at night to help cool the water wall and distributed mass in the building. Window and vent details should provide ventilation without compromising security.

Many people express concern about the potential for rust and leakage, but two techniques provide security: air-leakage testing, and either a rust-control additive (that is potable-approved), sacrificial anodes or coatings chosen to fit the application. (A sacrificial anode uses readily corrodible metal, often magnesium, attached to the metal you wish to protect; it will dissolve before the protected metal. Sacrificial anodes are widely used in water heaters.) Suspicious buyers of several water wall homes designed by SLSG have checked the water wall interiors after 20 years and found no corrosion. These tanks used sacrificial anodes.

Comfort, energy and financial savings, environmental benefits and aesthetic beauty — what's not to love about water walls? They should be one of the regular features an architect or solar designer considers in developing a building plan for any home, office, commercial building or industrial space. ●

Ken Haggard and Polly Cooper (slosg@slonet.org) are architects and principals in San Luis Sustainability Group: www.slosustainability.com. David Bainbridge (dbainbridge@alliant.edu) is associate professor, sustainable management, Marshall Goldsmith School of Management, Alliant International University in San Diego.

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