ENERGY WORKS

A passive solar-heated tower house

Integrates thermal mass, radiant floors, solar-heated water, natural ventilation, and solar-electricity.

By Stephen Heckeroth

This project is located on a four-acre parcel outside Albion, California, three miles east of the Pacific Ocean on a ridge above the fog. The home is a six-story, passive-solar water tower, planted between redwoods on three sides, yet open to the sun on the south side.

For many years, the clients had been visiting Mendocino, a historic coastal mill town dating back to a time when water was pumped by the wind and stored in tanks located on towers for gravity pressurization. They fell in love with the old towers and in 1979 went looking for someone to design and build a tower for their family's land on Caspar Point. The land at this site was best served by an earth-bermed structure, so the tower waited until a more suitable site was found. Construction began in 1993.

The owners asked for a house with very specific proportions based on their favorite towers located in the town of Mendocino, CA. They wanted privacy on every floor, room for 3,000 books and a collection of American oak furniture. Their wishes further included that the house be naturally heated, lit and ventilated, and have as many spaces for reading and dining as possible. The house should be practical enough to serve their needs, and whimsical enough to make them smile. Function and fun.

Above: Re-sawn redwood from the local area was used throughout the house.

Left: The finished tower house sits quietly in the redwoods. Note how the overhangs prevent direct sunlight from entering the house during summer.

Right: The greenhouse/sun space is a good place to relax and breathe oxygen-rich air.

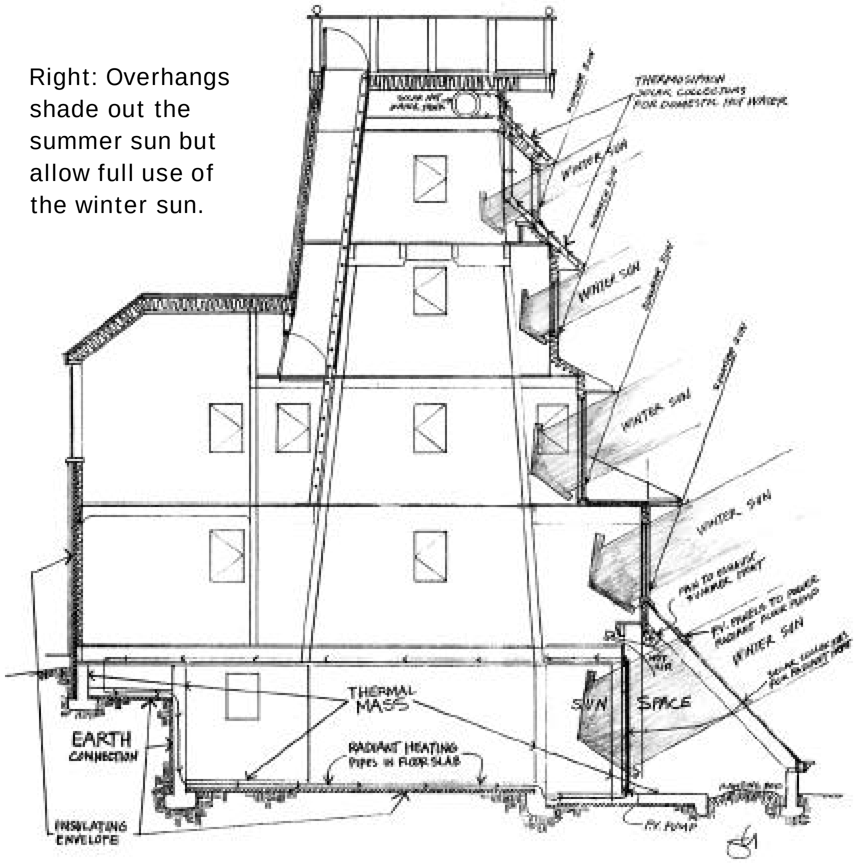
The design response to the client and the site was to nestle the 2,000-square-foot six-story tower and its 350-square-foot attached greenhouse/sun space into the earth on three sides and expose it to the south where a large clearing permitted good solar access. The tower house is heated by the sun and cooled by natural ventilation. Roof-integrated flat-plate solar collectors provide the domestic hot water. The pumps for the ground floor's solar-driven hydronic (radiant) heating system are powered by integrated photovoltaic (PV, or solar-electric) modules. The height of the tower is mitigated by redwood trees on the north, east, and west.

Energy efficient building techniques

The basic concepts and systems in solar design are orientation to the sun and wind, earth coupling to take advantage of the earth's (ground's) more constant temperature, thermal mass to absorb, store and radiate heat, and an insulating envelope to keep heat in or out.

The tower is oriented towards the south for solar gain. A sun space/greenhouse on the ground floor captures solar heat which naturally rises through the house, warming all levels.

Fifty yards of concrete were used in the foundation and below-grade walls for both its structural and thermal properties. The concrete provides thermal mass. The winter sun and a small wood stove are the only sources of heat necessary for the tower house. Overhangs prevent the high summer sun from overheating the tower. When windows are opened, the house works as a cooling tower. Hot air venting out



Right: Overhangs shade out the summer sun but allow full use of the winter sun.

the hatch on the roof deck, in turn, pulls cool air into the lower floors.

The fact that the first floor is buried on three sides takes advantage of the earth's more constant 60°F. This tends to cool the house in the summer and helps warm it in the winter.

The R-values associated with fiberglass insulation don't take into account plumbing, wiring, and framing members, which lower the overall insulation value. For this reason, rigid insulation was used. R-19 rigid foam insulation was wrapped around the entire structure above and below grade. This helps maintain a comfortable temperature by slowing the escape of heat captured in the thermal mass, and making it available to the interior space. R-11 foam insulation was used underneath the slab to prevent heat in the radiant floor from conducting itself into the ground.

Photovoltaic (PV) panels are mounted above flat-plate collectors on either side of the sun space/greenhouse. These supply the needed electricity to run the pumps for the lower solar-heated radiant floor.

Another set of flat-plate collectors is integrated into the shed roofs of the fourth and fifth floors. These use thermosiphon circulation to move heat into a hot water tank immediately below the roof deck.

Screened windows open on two sides of every room to allow ventilation without using fans or blowers. The light provided by these windows limits the need for electrical lighting until after sundown. Skylights have been added to two locations that might be otherwise dark. One is above the landing on the stairway up to the second floor. The other is a 6-foot by 12-foot triple-glazed translucent roof over the east end of the ground floor that makes the basement the brightest room in the house.

Resource-efficient materials

The house is built with a combination of concrete and wood. The 50 yards of concrete required to support a 50-foot tower house would usually be buried under the ground, particularly on the West Coast where few people have a basement. By designing the foundation to form retaining walls, the structural concrete serves the multiple functions of foundation, thermal mass, and earth connection. It also provides 300 square feet of comfortable living space at almost no extra cost.

The above-grade structure is built of the same material that surrounds it. The redwood beams were made from recycled, re-sawn timbers, as was much of the framework. The redwood trim was milled onsite from salvaged lumber. Tongue and groove, tight-grain, locally-milled Douglas Fir 2x6 serves as flooring on each level and the ceiling of the floor beneath. This construction technique exposes the beautiful redwood beams while decreasing the overall height of the structure by approximately one foot per floor. It also saves several steps in finishing and trimming the ceiling and allows the heat to move slowly up from one floor to the next.

All the windows were purchased at a great cost savings from a salvage yard that deals in high-quality insulated glass units. The house design accommodated the fit of the windows that were available.

Runoff from the roofs is collected in a reflecting pond immediately to the south of the house. This pond is used to irrigate terrace gardens further down the south slope.

Appliances were chosen for their low energy use and quiet operation. All lighting is full-spectrum capsule fluorescents which require one quarter of the energy of incandescent light bulbs. Low-flow plumbing fixtures were used to minimize water usage.

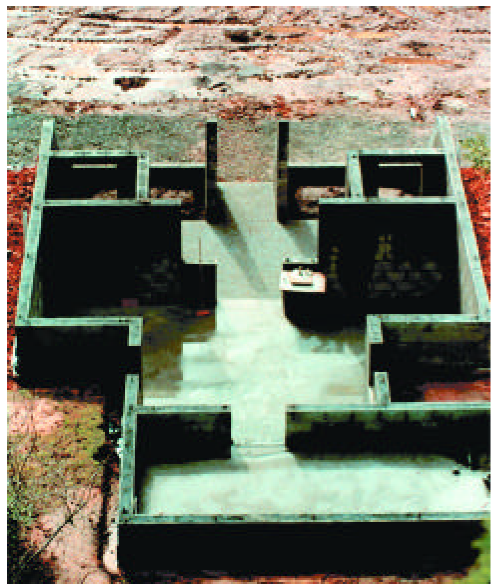
Many of the Mendocino water towers that the home imitates have survived over 100 years on much less substantial foundations. This home should last at least as long.

A healthful living and working environment

The owners enjoy a quiet and natural living environment. Their warmth

Left: The top soil from the building site was carefully separated and saved for a garden site

Right: Foam insulation and wire mesh are added. The hydronic heat pipes were tied to the mesh prior to the pour of concrete.



Left, above, & right: The foundation for the tower serves as structural and thermal mass and provides 300 square feet of comfortable living space.

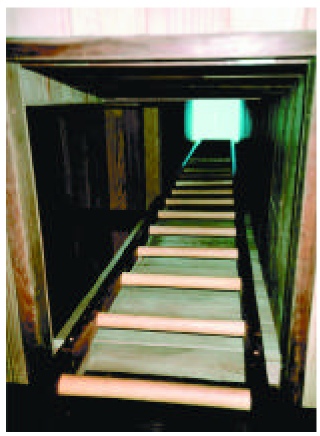
Right: The finished passive solar tower house

Above: The entire outside of the house is wrapped in an insulating envelope.

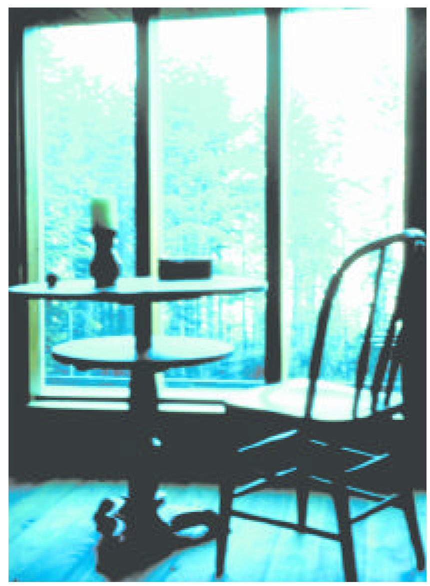
Right: The first and second floors under construction comes from the solar gain properties of the structure and the naturally rising heat that results. Ventilation is achieved by the opening and closing of windows. The location of two windows on every floor also helps in keeping the owner's book collection mold-free. There is no noise from mechanical fans. The owners can enjoy their morning drink on the east side deck, and their evening beverage on its twin on the west side. A hinged baseboard can be opened to allow heat from the greenhouse to rise up and warm cold feet. The Douglas Fir floors/ceilings, redwood trim, and beams are sealed with water-based products. Vegetables can be grown year-round in the greenhouse/sun space.

Left: The north side of the tower house.

Right: A view of the dining area from the kitchen



Right: A skylight hatch at the top of the ladder stays open during hot days to vent warm air. Regular stairs reach all levels.



Right: There are places to sit and write or eat on different levels.

Above: A translucent roof floods the ground floor with light.

Right: A fence serves as a wind break in the vegetable garden.

Cost and energy use

The entire labor and material cost of the 2,350-square-foot tower house was just under $200,000, or approximately $84 per square foot. This figure is 30% below the typical cost per square foot of custom-built homes in this area. The majority of the savings came from labor costs.

The owner, who is retired, worked full time starting a year before construction to gather materials, prepare the site, dig trenches, and sand beams. He kept the job site clean and organized through all phases of construction. When the house was finished, he continued to apply his incredible energy to dig a pond and create a permaculture landscape around the house.

The monthly electric bill has varied greatly since the house was completed in 1993. It ranges 4-14 kWh a day. This high, according to the owner, is due to visiting house guests who were unaware of when to open and close windows and hatches, using an electric heater instead. Another factor is the owner's own desire for cold drinks, which motivated him to install two small refrigerators, one of which ended up in the 90°F temperature of the sun space. This unit uses nearly 10 times the energy of the full-size Sunfrost refrigerator in the kitchen. (The lesson? It takes time to develop total energy awareness.) Even with these transgressions, the annual utility bill was $260 in 1994 and $438 in 1995.

The propane tank was filled once in the two-year period at a cost of $93. Propane is used only for cooking and clothes drying. The owners prefer to dry their clothes in the sun space.

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