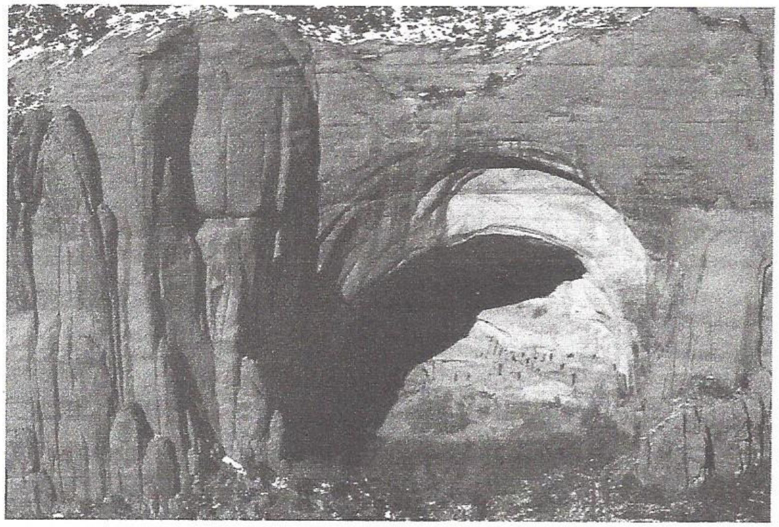
outside the wall," his wife, Holly, explained, "is a pane of glass[,] and on the outside of that is a big door. On winter days we open the door[,] and the sun shines through the glass and heats the water in the drums. When we close the door at night, the water [inside the drums] radiates warmth into the house.[16]

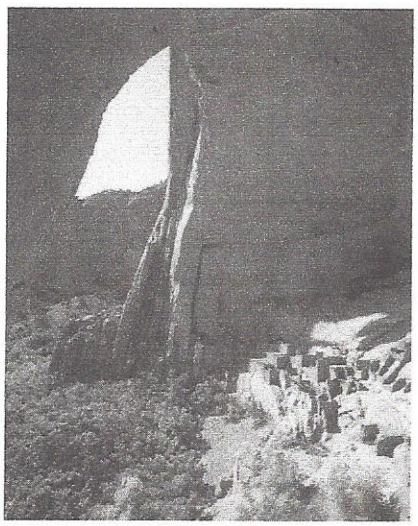
The Baers were part of a group that converged on Santa Fe, New Mexico, and shared a common interest in tinkering with solar applications. Another member of the group was David Wright, a licensed architect who had left a good job in Santa Cruz, California, to apprentice himself to Bill Lumpkin, a master adobe builder in Santa Fe. The solar collectors that Lumpkin, Baer, and some scientists from Los Alamos National Laboratory were experimenting with seemed too complex to Wright. The collectors circulated their heat via the forces of nature, but their construction required a substantial amount of additional materials, such as sheet metal, pipes, and water. Why not just make the house its own solar collector?

Rediscovering Solar Architecture

An earlier trip in the 1960s to Betatakin in the Navajo National Monument gave birth to Wright's vision. High above a canyon that Wright and others hiked through stood an entire village nestled in a cave that had been carved out of a cliff by the erosive forces of nature. The low winter sun, their interpretative guide explained, poured into the south-facing cave and heated up the heavy-walled structures inside. The heat moved through the walls and into the interior by nighttime, keeping the village's inhabitants sufficiently warm without recourse to any other fuel. Such architecture, the ranger explained, allowed them to survive where there was little wood to burn — owing to what he called their ancestors' shortsightedness.

Wright saw Betatakin with an architect's eyes and appraised the deserted village as "a very sophisticated use of low-energy materials and natural elements. It is a maximal use of obvious resources with an absolute minimum of technology, and it worked, as the ancient cave dwellers had only the cave and rock with which to make their buildings energetically self-sufficient." That fact he would never forget. "That impressed me," Wright recalled.[17] Further research revealed to the architect that other ancient peoples throughout history had done "variations on [the] same theme." "Look[ing] back and draw[ing] from history, it becomes increasingly apparent that the really hard work has already been





Figures 25.6 and 25.7. Distant and close-up views of cliff dwellings at Betatakin.

done," he concluded. Modern building technology, Wright recognized, could enhance what the ancients had accomplished with climate-sensitive architecture. "Just think how much more comfortable those Greek or Indian dwellings would have been," the young architect mused, "had they had double- and triple-paned glass on their south side to collect the solar heat or modern insulation to keep the heat in."[18] When Wright considered that he had at his disposal a far greater range of materials to work with, he knew that he could succeed in his mission.

With such insight, Wright realized that instead of using Steve Baer's water-wall idea he could substitute floors and walls that, if built properly, would retain the same amount of heat. He envisioned his building as a thermos bottle. He would keep the heated part — in this case the interior — warm by wrapping insulation around them. And he would aim the openings of his "thermos" house — the windows — to the south and "cork" it at night by closing them with movable insulation so the heat remained inside.[19]

In 1972 Wright designed and built a house according to this plan. A two-story double-glass wall formed the entire south side. The depth of the house was calculated so that the sun would penetrate the entire interior in winter. The house's thick adobe walls were insulated on the outside with polyurethane foam to protect those living inside from the winter cold and the summer heat. The roof was also heavily insulated, and the floor consisted of a relatively massive

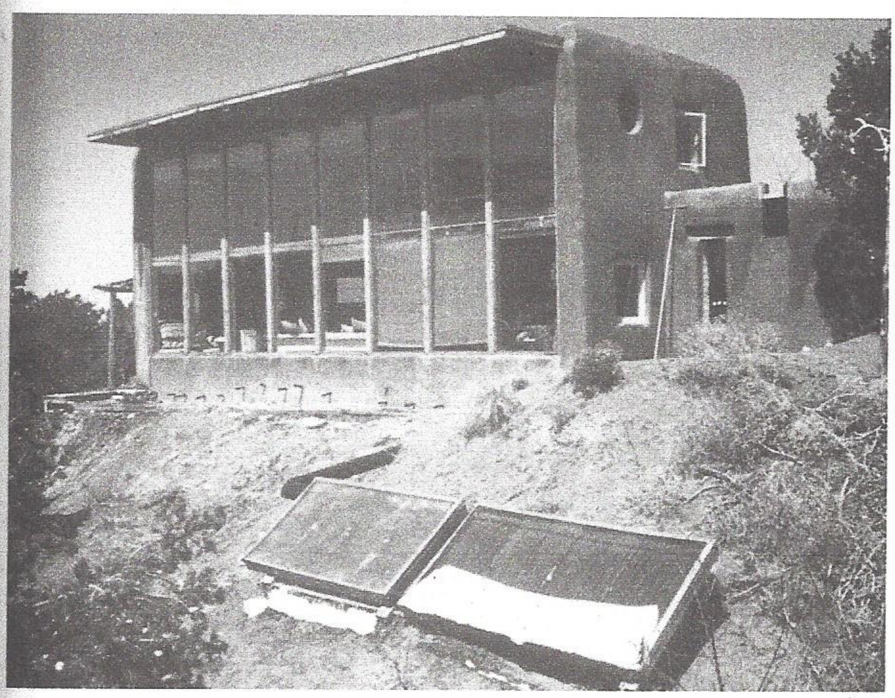


Figure 25.8. Wright's pioneering passive solar house, built in 1972. The auxillary heating system in the foreground were made unnecessary by the passive design and materials.

layer of adobe brick or sand with rigid insulation beneath. Tight-fitting, folding shutters opened and closed according to need.

Before Wright had finished the house, though, his scientific friends from Los Alamos dynamically modeled its future performance and became worried. "It might not work as well as you think!" one of them warned, and they advised him to install an auxiliary heating system. In response, he placed high-temperature tubing in the sand beneath the floor and planned to eventually connect it to solar collectors outside. The collectors never had to be connected, though. His Franklin stove generated the minimal amount of extra heat needed for comfort. Wright had to burn only a fraction of what others usually burned during the cold, snowy Santa Fe winters, and still the interior temperature held steady at a comfortable level. He was especially pleased with the loft where he and his wife slept, which, he discovered, "is great at bedtime as it is four to five degrees warmer upstairs."[20]

Sitting inside the house he called his sun ship, not long after the house was completed, Wright and some of his solar-energy-minded friends, including Steve Baer and the two scientists from Los Alamos — Herman Barkman and "Buck" Rogers — were chatting together. Wright asked the group: "So what type of system have I built?" Rogers replied, "Well, in mechanical engineering, we call systems that use pumps or fans 'active,' so I guess this must be a passive solar design." Wright later recalled that it was the first time he had ever heard the term *passive solar*, adding that "today *passive solar* design is known and practiced around the world."[21]

The 1973 Oil Embargo

Events far away in another arid region of the world should have spotlighted the work of these solar tinkers, or so it seems. In October 1973, the Arab oil-producing states cut back their exports to America in reaction to the nation's support of Israel in the Yom Kippur War. The ensuing shortage, *National Geographic* reported in 1974, brought about the greatest disruption in peacetime in the United States and much of the rest of the developed world since the Great Depression of the 1930s: "Factories shut down, workers were laid off, lights dimmed, buildings chilled, gasoline stations closed, Sunday driving was banned, fuel prices soared, stock markets fell." Petroleum geologist Marion King Hubbert,