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Umbrella Homes

A simple underground house design uses a novel insulating/water-shedding blanket that covers the structure and surrounding soil. The umbrella creates a huge subterranean thermal reservoir that soaks up the sun's energy during summertime and stores it for winter heating. In many cases, the clever design makes a heating system unnecessary.

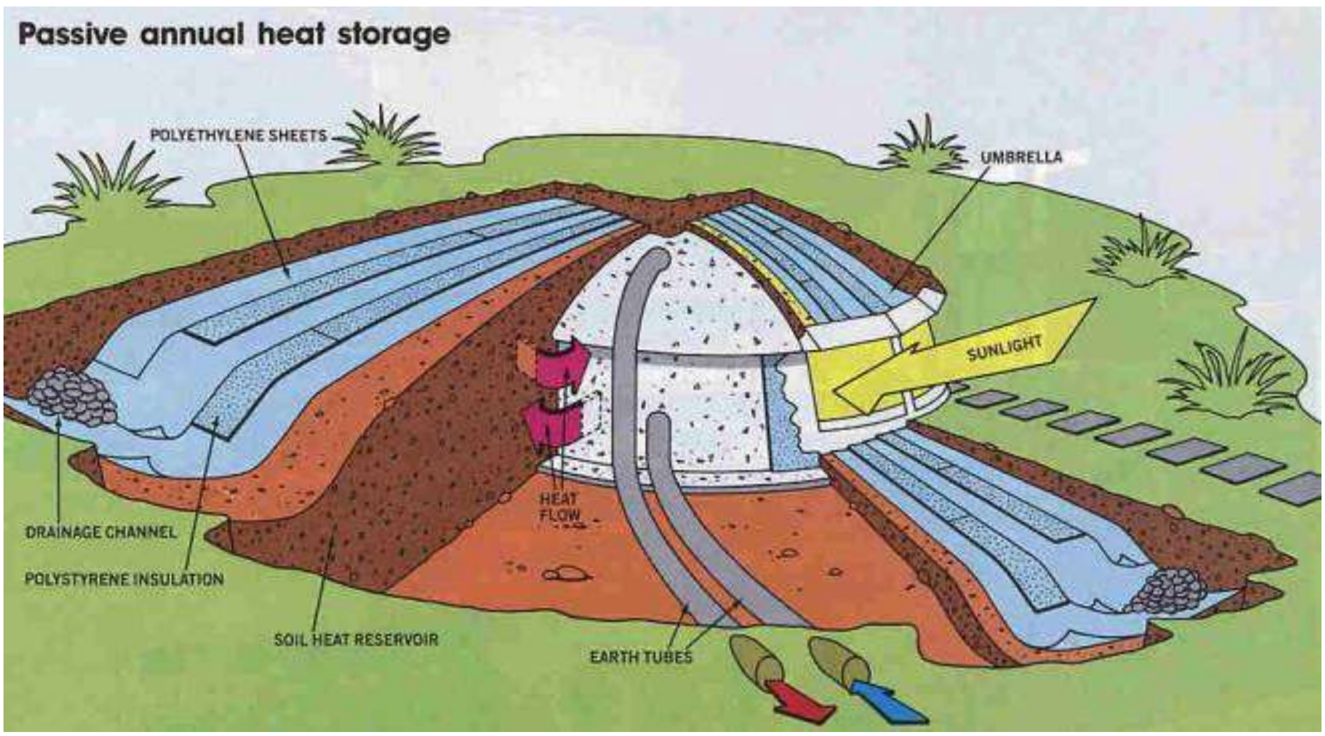

Figure 1 Geodome, the first umbrella home (in idealized form), maintains a 66° to 74° temperature year-round without heating equipment in western Montana's cold climate. In summer, solar heat radiates in, falls on internal surfaces, and is absorbed into the surrounding soil. The umbrella traps heat in the dry soil until winter, when it migrates back into the house. Adding convection-driven earth tubes would modify the internal temperature by conveying outside air in.

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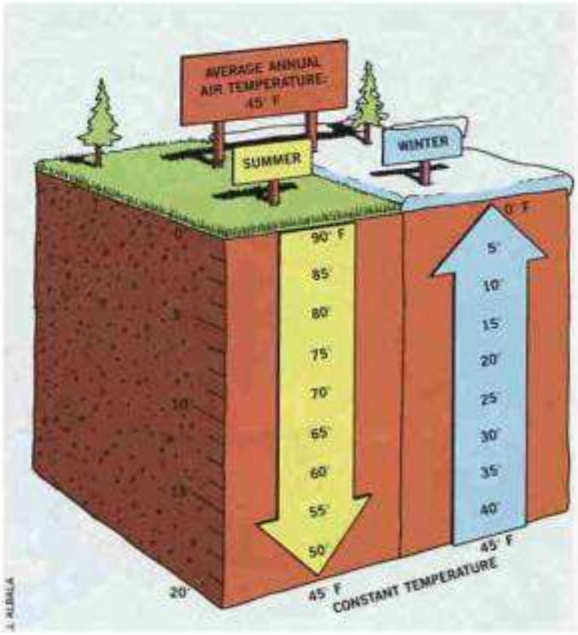

Figure 2 Twenty feet under the surface, the soil temperature reflects the average ambient air temperature during the year. In effect, the umbrella raises this constant temperature zone to the surface and allows the house to warm it further.

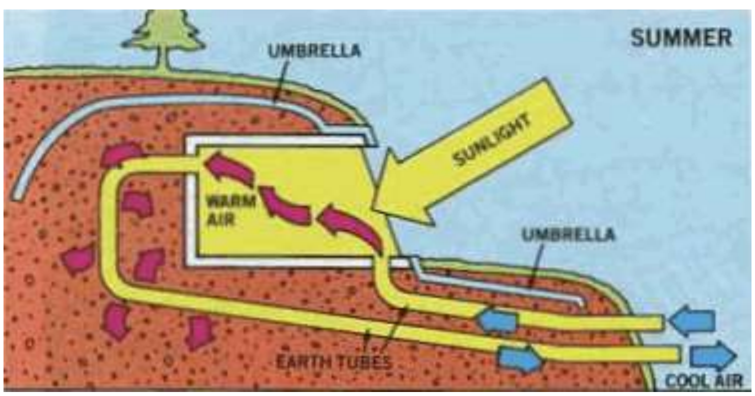

Figure 3a In summer, air enters the house through an earth tube and is warmed by the sun; moving through the second tube, it warms the cooler soil.

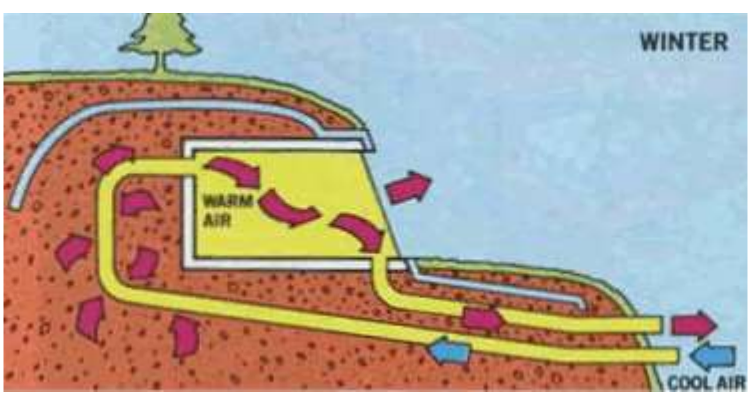

Figure 3b In winter, cool air enters, is heated by the warm earth, and passes to the house.

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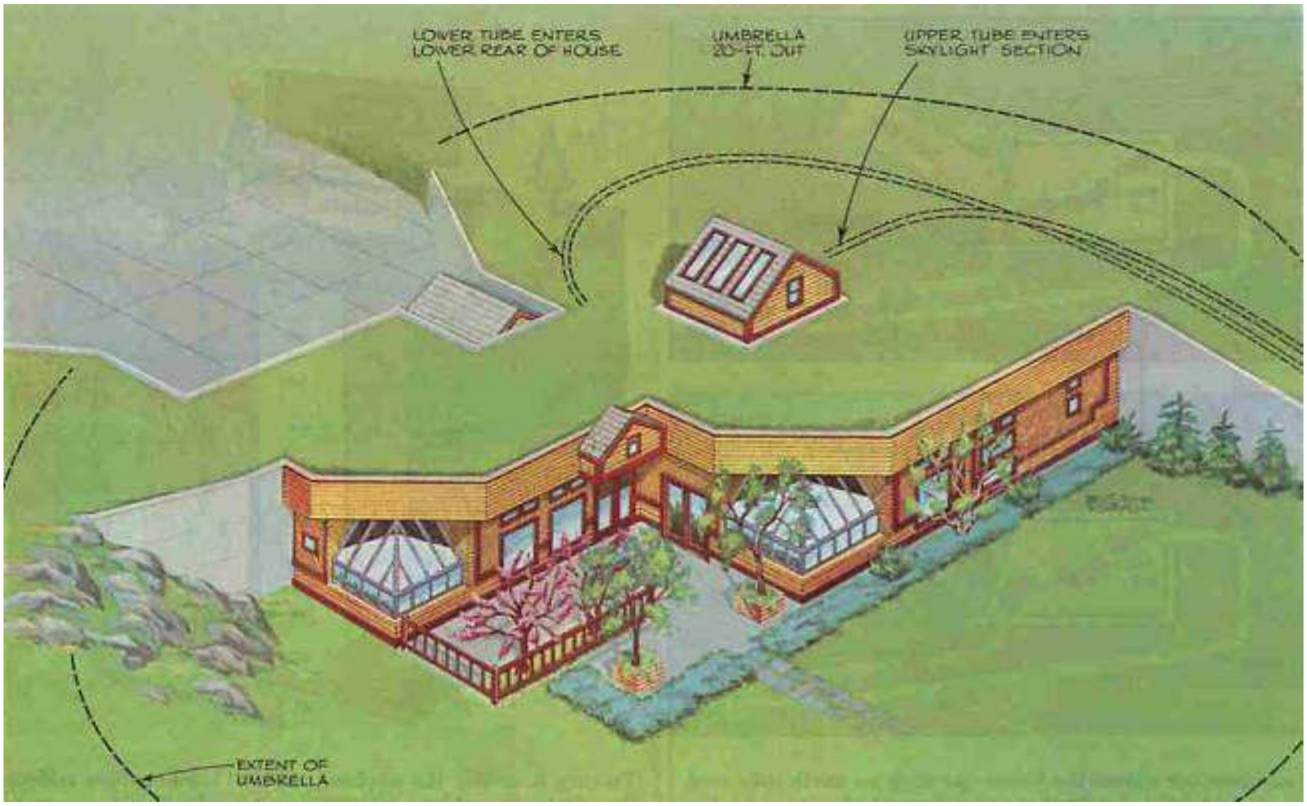

Figure 4 Second generation umbrella home in Missoula, Montana was constructed by Tom Beaudette, the engineer of Geodome.

By JOHN HAIT

My first earth-sheltered house, an underground geodesic dome was partially complete when the truckload of insulation my colleagues and I had ordered arrived. Right away, we knew we had a problem: How do you put flat, rigid polystyrene insulation on a round house?

We called housing experts all over the country, but no one had any ideas. Finally, Ray Sterling at the University of Minnesota's Underground Space Center suggested that we place a flat, insulating "umbrella" in the earth above the building. This, he said, would keep the domelike house warm by insulating the soil around it.

"What a marvelous idea!" I thought when I heard his advice. After two weeks of rigorous examination, I realized that the concept was even more promising than I'd supposed. By then I was convinced that the dry earth under an insulating/water-shedding umbrella could store enough free solar heat from the summertime to warm the house through the entire winter (see diagrams above). This meant that a house could actually be constructed with an unchanging built-in temperature, which would make heating and cooling equipment unnecessary. Now, five years later, I still think it's a marvelous idea. The Geodome, the house we built in the cold and cloudy climate of western Montana, remains at 66 to 68 degrees F, even through the coldest winters.

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The success of the Geodome led to the establishment of the Rocky Mountain Research Center, a nonprofit organization dedicated to the development of what is now called the passive annual heat storage (PAHS) approach to free year-round passive-solar heating. Four basic points make PAHS different from techniques used in conventional solar-heated earth-sheltered houses:

- The house's window shades are opened to collect solar heat in summer.
- The umbrella's laminated sandwich of polystyrene insulation and polyethylene sheeting (about R-20) insulates a huge mass of surrounding dirt instead of just the house.
- The umbrella sheds water to keep the soil around the house dry.
- The natural-convection-driven ventilation tubes (see below) provide very high heat retention efficiency by acting as counter-flow heat exchangers.

Conventional passive-solar theory tells us to exclude the abundant summer sunshine by blocking it out with large window shades because the typical (relatively small) thermal mass in a solar house can store only a night's worth of heat. Yet we're also told to make the windows large enough to capture what little solar heat we can in winter. PAHS, on the other hand, uses the summer's abundant sunshine to heat up a large body of earth around the house to a comfortable 72 degrees F or so. That warm thermal mass keeps the house and its occupants cozy all winter. Simple thermal conduction transfers heat through the walls, into the soil, and back.

Twenty feet underground, the natural soil temperature is nearly constant (see diagram), and is equal to an average of the entire year's worth of temperature changes on the surface. The Geodome's inexpensive umbrella isolates the soil beneath it from fluctuating outdoor air temperatures above. By controlling the heat flow in and out, the blanket raises the constant soil temperature around the structure to reflect the newly established average annual air temperature inside the house. The result is a comfort able indoor temperature that varies only six or eight degrees during an entire year, while outdoor air temperatures may vary from minus 40 to more than 100 degrees F.

Although the Geodome's window area amounts to about six percent of its floor area—less than most solar homes —the summer sunshine lasts much longer, and so more solar heat is collected and stored away than is available from any passive winter thermal-collection system.

We've learned several lessons from the Geodome that have advanced our understanding of integral year-round thermal systems. First, the design temperature of 66 to 74 degrees is built in and is difficult to change. This became apparent during its first winter. The Geodome's tenant at that time, a salesman who was constantly on the road, found that the house temperature was still at 66 degrees F in March—even with a few warm bodies or appliances to add heat. We realized then that if you would like it a little warmer or a little cooler in such a house, you would have to enlarge the window area and install adjustable shades. That way, the annual solar input could be altered to modify the internal temperature as desired.

Second, thermometers indicated that the umbrella altered the ground temperature much farther out from the walls than we expected. I located some National Bureau of Standards studies that showed that air-temperature changes affect the soil temperature more than 20 feet down into the earth, so we concluded that the umbrella should be extended to at least that distance beyond the walls.

Third, an examination confirmed that the earth underneath the umbrella was bone-dry, even though the soil on top was moist. The dry dirt below makes waterproofing the structure easier, while the moist soil above helps alleviate the desert-like conditions that often occur on top of many earth-sheltered houses. Note that the water table must not moisten the thermal mass.

PAHS seemed to offer a way to build energy-efficient homes that require no commercial energy supply for heating or cooling, but we realized that to become truly practical, we needed to provide for ventilation, heat retrieval, and moisture control.

No good solution presented itself until one day when I was teaching a class of students at the center about convective heat flow. After a time, the discussion turned to-ward the use of earth tubes—pipes in the ground that bring in outside air for ventilation. Then one of the students asked about convective heat flow in earth tubes. Before I knew it, the solution to our problem was sketched on the chalkboard: an open-loop, convection-driven earth-tube system (see diagram) that draws outdoor air into the house to be heated by the summer sun, transfers it to the buried earth tubes where it passes some of its warmth to the relatively cool soil, and finally exhausts it outside. In winter, the cycle would reverse itself.

Essentially, the earth tubes act as heat exchangers: If the air in the tubes is warmer than the earth, the earth soaks up and stores the heat. If the soil is warmer than the air, it gives up heat to the air flowing through the tubes (see diagram). In this way, the temperature of the outside air can be altered to provide the house with warm fresh air in winter and cool fresh air in summer.

The tubes themselves must be very long (between 150 and 200 feet) so they can snake their way back and forth through the soil under the umbrella. (For clarity, the tubes in the diagrams are shown straight rather than bent.) Typically, we use earth tubes that are between four and eight inches in diameter. We lay each pair out under the umbrella so that they slant downhill from the house to permit water runoff and so they both exit the ground at the same elevation.

This type of earth-tube arrangement differs considerably from the earlier "cool-tube" installations, which have been in use for some time. A single cool tube allows air to flow only one way—into the house. The house can inhale, but it cannot exhale. To exhaust stale air in winter, a window or vent must be opened, which would dump large quantities of heat outside. Also, lacking the insulating/ water-shedding umbrella, cool tubes do not have the warm earth environment that allows the air in the tubes to be heated as well as cooled. Properly coupled, the open-loop, convective-heat-flow earth-tube system and the PAHS sys-tem can provide free, year-round heating, cooling, and ventilation for the earth-sheltered home.

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This still-experimental housing technology is already being used to satisfy at least a portion of the heating needs for several recently constructed earth-sheltered homes. It is also being built into a number of full-fledged PAHS earth shelters, such as the house depicted above, which was constructed by Tom Beaudette, the engineer of the Geodome.

Detailed explanations of these concepts are provided in mthe 152-page book: *Passive Annual Heat Storage, Improving the Design of Earth Shelters*. It's available directly from the Rocky Mountain Research Center

NOTES: This information is largely reproduced from Popular Science, August 1986, pages 64-66.

John Hait's book, PASSIVE ANNUAL HEAT STORAGE, Improving the Design of Earth Shelters, is still the best available book on PAHS. You are cheating yourself if you don't read it before building ANY earth sheltered home.

This information was provided by Joe Anderson, a mechanical engineer interested in the adaptation of PAHS principles to various climates and owner requirements.

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