

Energy Advantage

Oregon Dome Information Series #8

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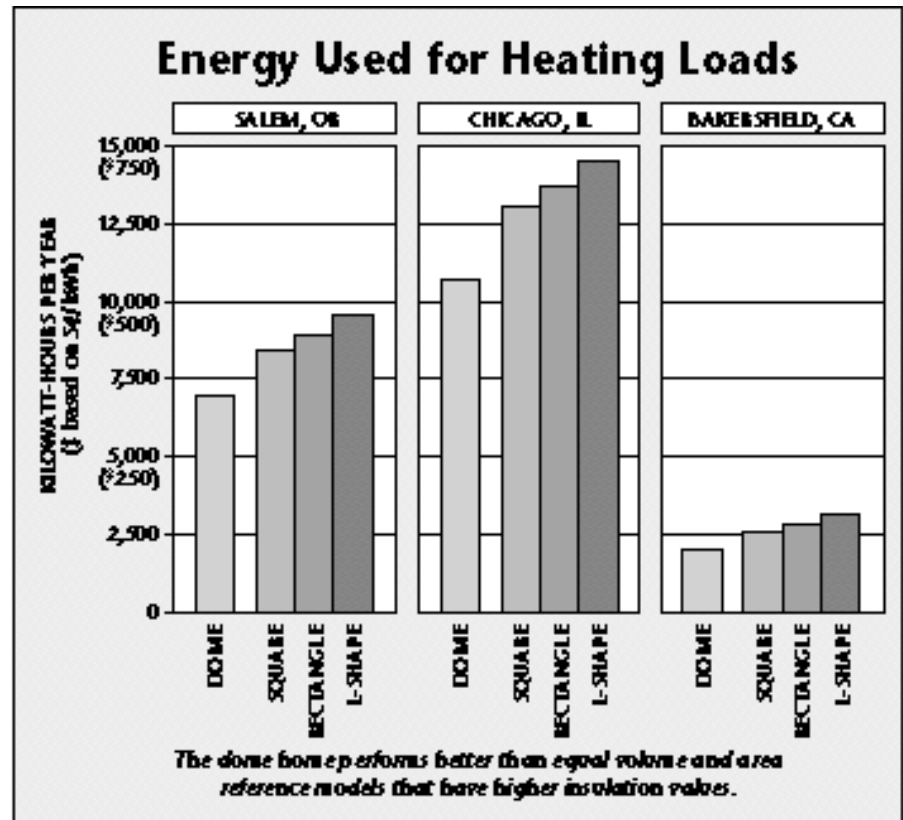
Energy use in houses is usually dominated by heating/cooling/ventilation loads. Heating loads are primarily affected by *conductive loss* through the building surfaces and by *infiltration loss* caused by air leaks.

Oregon Dome homes benefit from a naturally efficient geometry and quality-constructed components that reduce both types of thermal loss. Lower heating and cooling loads mean lower energy costs. With average energy savings reaching 28%, there is considerably less demand for gas and oil and on electricity generating plants.

Energy Use Simulation Study

In order to demonstrate the cumulative energy-saving benefits of several of the concepts discussed in this report, we had an energy analysis performed to compare our dome home to conventional construction using a sophisticated computer simulation program (DOE2.1E). In the study we compared our 45' foot, no-riser dome configuration to square, rectangular, and L-shaped reference plans.

The graph at right shows that Oregon Dome homes require less heating than all three reference models. More complex designs would perform progressively worse. Each reference model was designed to have the same building volume, first floor area and total floor area.



In addition, the square footage and orientation of windows was made equivalent in all simulations. Heating energy

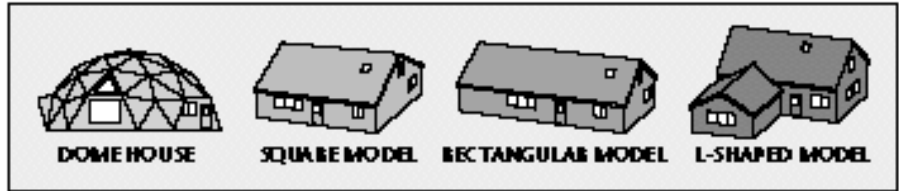
demand was modeled in all four cases using an electrical resistance system typical for residential studies.

In A Nutshell...

- Small surface area to volume ratio allows less conductive heat loss through building envelope
- Less foundation perimeter means less edge loss
- Tight construction reduces infiltration loss
- Building geometry lowers pressure change from wind which reduces infiltration loss
- Sphere enhances stack ventilation potential

For the reference models, insulation levels were set to Oregon Energy Code standards which meant that they actually had higher average insulation levels than the dome home model. In order to obtain comparable volumes and quality of space, vaulted ceilings were assumed for the reference models. In these simulations the roofs have required insulation levels of R-30 and the walls have R-21 and the dome panels are modeled with insulation levels of R-21. All other materials were considered the same.

Constant infiltration rates were set at 0.35 ACH (air changes per hour) for all simulations in order to meet minimum ventilation requirements. An additional wind variable infiltration of 0.15 ACH was included for the reference models to simulate an overall 0.50 ACH which is a median rate for new construction in North America (*ASHRAE 1993 Fundamentals*, 23.10). As discussed below,



domes have been shown to be much tighter than this median.

Less Building Surface Area

As an intrinsically efficient geometry, domes have a lower surface area to volume than any other housing form. The less surface a building exposes to the elements, the less conductive heat loss there is through the building envelope.

The chart below compares the overall wall and roof surface area of the buildings modeled in our study. It shows that, for the same floor area and volume, a dome home has up to 28% less surface area which means less exposure to differences between indoor and outdoor temperatures.

Smaller Foundation Perimeter

For houses built on a slab-on-grade foundation, heat loss through the floor occurs mostly at the slab perimeter rather than directly through the floor into the ground (*ASHRAE 1993 Fun-*

damentals, 25.12). Heat loss is considered to be proportional to perimeter length which means that for a given area, the most energy-efficient floor layout would have the smallest perimeter, and resulting edge loss.

Using the same house models described earlier, the figure to the right demonstrates how the dome house has up to 27% less linear feet of perimeter which translates directly into a reduction in heat loss. This is because the circle has the lowest perimeter to area ratio of any planar geometry.

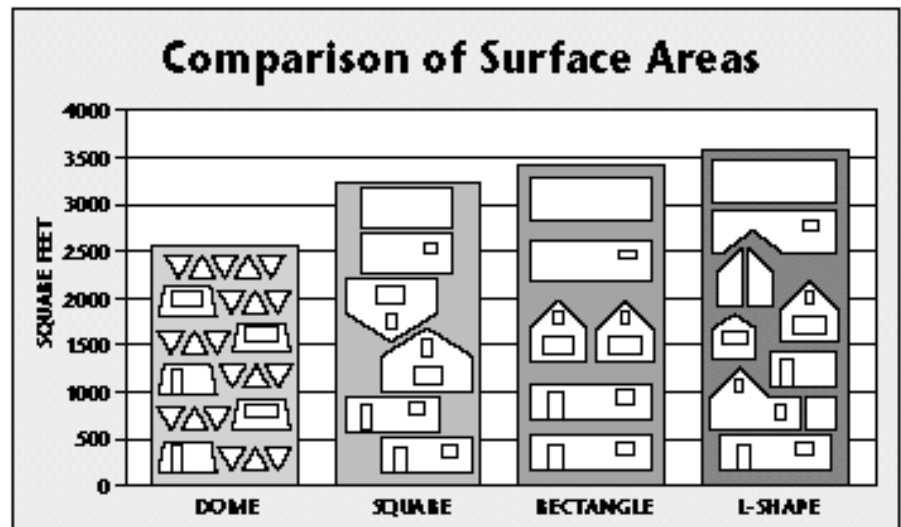
Tighter Construction

The other major source of heat loss or gain is from infiltration loss caused by ventilation and air leaks. Proper ventilation, of course, is required for the health of a building's occupants. For houses, which generally have a low relative occupant density, this requirement is usually

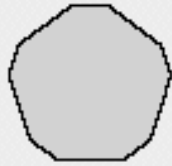
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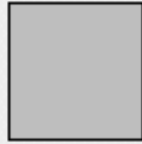
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Comparison of Perimeter Length



DOMES FOUNDATION
Perimeter: 138.8 Lf.



SQUARE FOUNDATION
Perimeter: 153.2 Lf.



RECTANGULAR FOUNDATION
Perimeter: 164.8 Lf.



L-SHAPED FOUNDATION
Perimeter: 175.8 Lf.

Given the same first floor area, linear feet of perimeter is lowest in a dome foundation, which means less edge loss.

much lower than the natural infiltration caused by air leaks in the building envelope. These air leaks are caused by poor construction techniques that leave small cracks at building joints and window and door installations. Because Oregon Dome's panelized triangles are manufactured under controlled conditions, they fit together better and allow fewer cracks and less air leakage.

To demonstrate the tightness of an Oregon Dome home, we performed several blower door tests on a typical 45-foot dome. This diagnostic tool increases the pressure differential in a building which makes it possible to measure air leakage rates. In our tests the dome had an average air leakage rate (CFM10) of 185 cubic feet per minute, which translates into

an estimated natural infiltration rate of 0.07 ACH. This is far tighter construction than the median value of 0.50 ACH for new construction mentioned earlier. Tighter construction allows for better control of heat gain or loss through air leaks.

Building Geometry

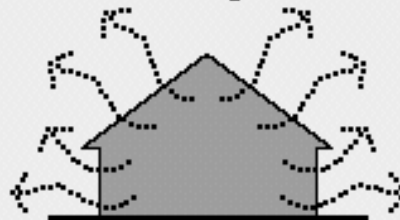
Infiltration can be defined as uncontrolled air flow through unintentional openings, such as building cracks. It is a function of the tightness of the house, as described below, and the pressure differential between the inside and the outside. This pressure drop which forces unconditioned air through holes in the building skin is a result of wind speed and building geometry. Put simply, the less resistance a building form offers to wind pressure, the smaller the

pressure differential at the building skin. This means less infiltration loss.

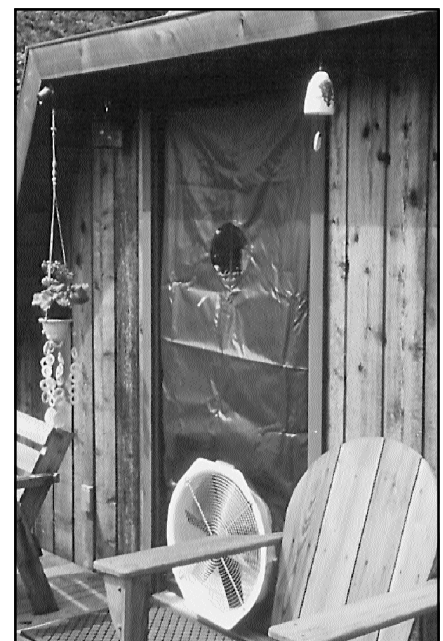
The diagram on the following page illustrates the principle of how the dome shape reduces wind resistance and lowers pressure differentials. Studies using wind tunnel tests have shown that a typical rectangular residential structure has external pressure coefficients of +0.9 on the windward surface, -0.5 on the leeward and -0.7 on the side walls. The similar pressure gradients measured for hemisphere domes range from +0.2 to +0.6 windward, -0.2 to -0.04 leeward and -0.6 to -0.7 at dome sides (*Windloading Handbook*, pg. 63). This means that the potential for infiltration loss is lower for dome shapes as a result of their lower resistance to wind.

Actual energy savings are highly dependent on local wind conditions and were not included in the simulation study.

Comparison of Air Leakage

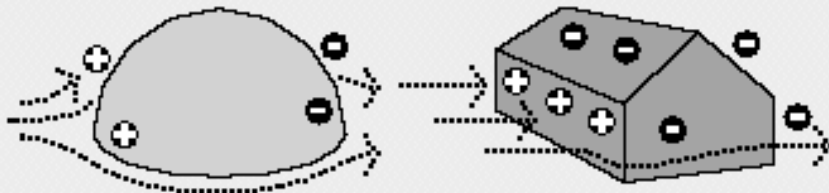


Air leakage was measured to be over 85% lower than the median rate for new construction in North America.



Blower door test used to demonstrate low air leakage rates.

Comparison of Wind Pressure Resistance



Domes offer less resistance to wind pressures so there is less infiltration loss.

Stack Ventilation

Though not analyzed in the simulation study, another demonstrated energy benefit is the potential for enhanced stack ventilation that dome geometry provides. This passive cooling technique occurs when warm air rises and is allowed to flow out of a room, replaced by cooler outside air from lower inlets, as illustrated at right. This effect is optimized with high ceilings that have an operable skylight or cupola located at their peak as is designed in the Oregon Dome.

This type of ventilation flow is further enhanced by the dome's shape because the outlet

is at the location of highest negative pressure on the building envelope, regardless of wind direction. This negative pressure creates suction which helps pull the hot air out of the house.

Summary

Oregon Dome homes benefit both from quality construction techniques and from the advantages of their energy efficient shape. A dome's minimal surface area as compared to volume, and its minimal foundation perimeter as compared to area, reduce the potential for conductive heat loss or gain. The tight building envelope that results from panelized construction reduces infiltration

loss. Additionally, the open, high ceilings of the interior provide greater potential for improved ventilation and daylighting, which in turn reduces energy use even more. In the final analysis, the Oregon Dome provides a considerable energy advantage over the typical house design.

Analysis was conducted by the Energy Studies in Buildings Laboratory at the University of Oregon as part of the Energy Efficient Industrialized Housing project sponsored by the U.S. Department of Energy in cooperation with the Building Systems Council of the National Association of Home Builders.

Effect of Stack Ventilation



The dome shape facilitates passive ventilation.

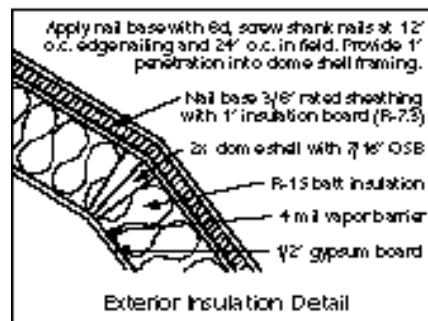
The Ins & Outs of Insulation

The dome used in this study was a 45'0", 2x4 dome with the exterior insulation package, pre-cut and ready to install the day after dome raising. Exterior insulation addressed the framing of the dome, in the spirit of doing "more with less."

In wood frame construction, with 2x4 or 2x6 framing, fiberglass insulation is installed between the studs only. This leaves the studs themselves virtually uninsulated. Since framing can comprise up to 20% of a home's total exterior wall and roof area, a significant energy loss can occur through wood, which is better insulation than steel, yet only R-1 per inch. Insulation is rated by an R-value, which is the measurement of the resistance to heat flow. The higher the R-value, the greater the insulating value.

Often the first thought when energy efficiency is desired is to increase the framing

to 2x6 to accommodate R-21 insulation. Instead, the exterior was insulated creating an envelope. The cavity remains accessible for easy unloading, dome raising and wiring. The R-15, unfaced, fiberglass batt insulation was installed in a rational construction progression.



The exterior insulation, R-7.3 rigid polyisocyanurate insulation not only boosts the insulation in the cavity to R-22.3, it doubles the effectiveness of the 20% of the building that is framing, even if 2x6 studs (R-5.5) are used. This is often ignored when considering insulation in homes.

The polyisocyanurate foam is manufactured with blowing agents that are environmentally non-damaging. An inch of insulation is too much thickness to roof over, so another layer of rated sheathing is provided over a felt product. This allows the building to breathe with the single vapor barrier provided on the warm side of the home, behind the sheetrock.

The 2x4 dome better utilizes second growth wood. It is easier for a smaller crew to unload and assemble a 2x4 dome. Even a 50' dome can be raised without additional people or mechanical assistance.