COUNCIL NOTES

C2.3 ILLINOIS LO-CAL HOUSE
THE "ILLINOIS LO-CAL HOUSE"

The increasing scarcity of fuels makes it imperative to include more energy-conserving features in our housing.

This publication describes the design, construction, and predicted performance of a house which uses about one-half the energy needed to heat a house of the same size which was built to meet 1974 insulation standards (U.S. Department of Housing and Urban Development standards for houses located in areas having a heating season of between 4500 and 8000 degree-days). Because of its low energy requirements for heating, it has been called the "Illinois Lo-Cal House." If the Lo-Cal House is compared to the typical house of 1950, the savings are even more dramatic.

A comparison with a house built to the 1980 HUD standards is also included. It should be noted that the level of insulation recommended in the new minimum standards is approaching the super-insulation recommended in the first Lo-Cal publication in 1976, which was considered extreme at the time.

The major features which account for the exceptional reduction in energy usage are:

- Superior insulation
- Solar orientation

Of the reduction, about 90% is due to the extra insulation. The remaining reduction is due to the location of most of the windows in the south wall, where they act as solar collectors.

DESIGN AND CONSTRUCTION FEATURES

Insulation
- Heavy ceiling insulation
- Heavy wall insulation
- Improved floor and crawl-space insulation
- Triple-glazed windows
- Complete vapor retarder (barrier)
- Tight construction to minimize air leakage

Solar
- Major axis of house oriented east-west
- Roof overhang designed for solar control
- No windows on the east and west walls
- Major glass areas on the south wall

General Features
- Can be built with standard, readily available building materials
- No new technology or labor skills required
- Design conforms to current practice
- Design adapts to various lot orientations

Benefits
- Low-cost heating system
- Low energy use for heating
- Low-cost cooling system
- Low energy use for cooling
- Favorable ratios of benefit to cost
- Improved acoustic performance

CONSTRUCTION DETAILS

This design is considered appropriate for most areas of the United States having a heating season of 4500 degree-days or more.
Design A. The basic plan was designed for use on a lot with the street on the north.

1. The living room and bedrooms are arranged on the south side of the house.
2. The family-kitchen area is on the north; however, it opens to the living room, from which it receives solar benefits.
3. The entrance vestibule, baths, utility and storage areas are also on the north.

**Roof-Ceiling Construction**

The roof-ceiling construction is designed with the bottom of the overhang (soffit) at the same level as the ceiling of the house. This simple modification of the usual roof-ceiling framing provides space to extend the thick ceiling insulation over the outside wall and still maintain adequate ventilation space above the insulation.

Twelve inches of insulation, combined with the ceiling structure, provides a total thermal resistance (R) of 38, compared with an R of 19 for the 1974 house and nearly equal to the R-33 of the 1980 HUD house. A complete vapor retarder (barrier) is located immediately below the ceiling insulation. This may be a 4-mil polyethylene film or an aluminum foil on the back of the ceiling finish material.

**Outside Wall Construction**

The outside wall is composed of a double-framed wall with staggered studs 24 inches on center and spaced so that it is 8½ inches from the back of the sheathing to the back of the interior finish. This provides space for insulation which, combined with the other elements of the wall, results in a total thermal resistance (R) of about 30. This is more than twice the insulating value of the 1974 house and about 1½ times the 1980 standard for a house with electrical resistance heating.

4. Most of the windows (85%) are located on the south wall. The remaining windows are to meet code requirements for light and ventilation. There are no windows in the east and west walls. This is the best arrangement for thermal efficiency of the house. East and west windows should be used only when view is a prevailing requirement. In such cases, the windows should be small and well shaded in the summer.

A vapor retarder (barrier) must be provided at the interior surface of the inner stud wall. Polyethylene film or foil-backed gypsum drywall is suitable for this application. Either blanket- or fill-type insulation may be used. The thickness of the wall may be varied in accordance with the climate and energy costs.

There are several benefits of using a double wall. Since the studs do not touch, there is minimal heat lost through the framing. During construction, electric wires can be run between the double walls without drilling, reducing insulation damage and possibly labor costs. The slot between the top plates of the wall permits any moisture which gets into the wall to vent into the attic space. The thick, insulated wall and triple-glazed windows also reduce sound transmission.

**Floor-Foundation Insulation**

The most effective way to reduce the heat loss through the floor is to insulate both the floor of the house and the outside wall of the closed crawl space. The Lo-Cal design uses R-19 insulation in the floor and R-10 insulation on the perimeter wall of the crawl space. When practical, hot-water pipes and heating ducts (if any) should be above the floor insulation. A polyethylene vapor retarder should cover the dirt surface. If heating ducts are in the crawl space, then it should be...
Roof truss with ceiling and soffit at same level allows thick insulation and air space for ventilation

Roof overhang designed for solar control

Continuous soffit and ridge vents allow moisture from the attic space to escape and also reduce attic air temperature

* If ductwork is run in the crawl space: 1) Use no floor insulation; 2) Seal all duct joints well; 3) Increase the perimeter insulation of the crawl space to at least R-19; 4) Seal the crawl space, including vents.

HORIZONTAL SECTION OF WALL

VERTICAL SECTION OF HOUSE
treated as a heated space. The outside wall should be insulated to at least R-19 from the bottom of the floor to at least 24 inches below ground level, and R-10 from that point to the bottom of the wall.

Window Design
The triple-glazed windows of the Lo-Cal house are designed for low heat loss and optimum solar gain in winter and for reduced heat gain in summer. The design is based on a study which shows that the solar heat gain minus the heat loss of south-facing, triple-glazed windows can average up to 200-400 Btu per square foot per day. In the one-story plan, 85% of the window area is on the south wall. Small windows on other walls may be installed for view or ventilation.

Triple-glazing consists of three panes of glass, and can be a standard window with sealed insulating glass plus a storm window, or a factory-sealed triple unit. For the Lo-Cal House, a 50-inch high window was chosen. This height matches a roof overhang which is 16 inches above the top of the window and extends 30 inches out to the edge of the gutter. The south windows are exposed to sunlight in the winter and are shaded in the summer. In late summer and early fall, when the window is only partly shaded, shade screens or other devices can reduce heat gain.

Since the house is so well-insulated, the 122 square feet of south windows provides enough solar gain while reducing heat losses at night and during bad weather. The south glass area is about 8% of the total floor area of the house.

A Tight House
Air infiltration or air leakage can be one of the most significant factors influencing the heating load. Infiltration around windows, doors, and gaps in the construction becomes more important as the heat loss through the other parts of the house becomes smaller. As the tables show, the house must be built tighter to get the maximum benefit from the extra insulation.

### Heat Loss Calculations
Table 1 summarizes the heat lost through the five component surfaces and from air infiltration from the 1974 house, a house built according to the requirements of the 1980 HUD standards, and the Lo-Cal House. These calculations are made in accordance with accepted engineering practice and do not include solar gains or internal heat gains.

#### Heating System
In the weather simulation for Rantoul, Illinois (1957, 5890 degree-days), the maximum heat loss of the Lo-Cal House is computed to be 20,990 Btu per hour. A number of options are available for the heating system.

The system with the lowest installation cost would be individual room electric heating, such as baseboard units located under the windows. These units would have a total rated output of only 7 kilowatts, and the advantage of individual room thermostatic control. A natural-gas-fired central system or heat pump would cost more to install but, depending upon economics, might have the lowest 10-year cost.

#### Cooling System
For mechanical cooling, small, individual room units could easily cool the house. Although they offer the advantage of individual room control, they are noisier than a central cooling system.

A central system using an outdoor air-cooled condenser can be provided at fairly low cost. The cooled air can be distributed through an overhead duct located in the central hallway. At a higher cost, the air-handling system can be designed to bring outdoor air into the system when outdoor air cooling is adequate.

#### Exhaust Fans
Kitchen and bathroom exhaust fans, either manually or automatically controlled, will remove excess heat and moisture from cooking and bathing. In colder regions where the tightest construction is used, air-to-air heat exchangers should be considered to maintain air quality and conserve energy.

#### Solar Mechanics
Sunlight through the windows heats the interior surfaces of the house; the structure and furnishings absorb heat and warm the air; insulation keeps the heat in the house, even after sundown. With maximum insulation and major south windows of insulating glass, the house itself becomes a cost-effective solar collector.
The net heat gain (or loss) of a window varies with the latitude, month, window orientation, solar transmission, heat transmission, outdoor temperature, atmospheric conditions and percent of sunlight, reflected sunlight, and shading of the window. With the seasonal change of sun angle, the direct ray solar gain of south-facing windows is highest of all in winter, moderate in spring and fall, and lowest in summer.

The daily solar gain of a south-facing, triple-glazed window may exceed the average 24-hour heat loss through the window; this net heat gain may be as much as 400 Btu per sq. ft. per day during the heating season. In some regions with more sunshine and snow cover, the gain may be higher. Generally, this benefit of triple-glazed windows applies to the cold areas of the United States. In climates with less than 4500 degree-days, south-facing double-glazed windows have similar benefits.

Shading. While the south-facing windows provide solar heat for the house from October to April, the windows should be shaded to minimize solar gain from June to October.

- Trees. Deciduous trees are most useful because they are in leaf during the warm season of the year when shading is needed. They do not interfere with winter solar gain since their leaves have fallen before the heating season.

- Roof Overhang. With the seasonal change in sun angle, the roof overhang above the south windows can be designed to achieve the amount of shading or sun exposure desired.

- Other Shading Devices. Awnings, shade screens, shutters, blinds, foils, or draperies can limit solar gain of windows. For example, in conjunction with a roof overhang, shade screens over the lower half of windows can stop most of the solar gain of south-facing windows in August and September.

The illustration shows the sun angle for a latitude of 39° with the profile of the roof overhang and south windows of the Lo-Cal House. At 43° latitude, the south windows are over 90% exposed to the sun from October 21 to February 21. From April 21 to August 21, the south windows are shaded 80% or more. The roof overhang could be designed to shade the window all summer; however, this is not desirable since it would also shade the windows and seriously reduce the solar gain during the spring heating season. Therefore, some other shading device should be used to block the sunlight during August and September. See Circular 3.2, Solar Orientation, for shading angles at other locations.

PREDICTED PERFORMANCE

Actual heating costs for the Lo-Cal House are being verified by building and testing a demonstration house under controlled, monitored conditions. Full-scale confirmation of predicted results will require the building of a number of lived-in houses in widespread areas of the United States and Canada.

Since, as yet, demonstration house studies are not completed, the best alternative is to make a thorough engineering analysis, taking into account all energy inputs to the Lo-Cal House. For this purpose, a predictive computer program* was used, and weather data for Rantoul, Illinois, in 1957 was selected as having typical characteristics.

Assumed Conditions

Calculations of energy requirements for all three houses are based on the same conditions of weather, range of internal temperature, and internal heat gains. The HUD 1974 house was calculated on the basis of an air infiltration rate of 1 air change per hour, the 1980 house at 0.75 and the Lo-Cal House at 0.6 air changes per hour due to its tight construction. In both standard houses, the windows were placed with one-third of the total window area on each of the north and south walls and one-sixth on each of the east and west walls.

* U. S. Army Corps of Engineers, Construction Engineering Research Laboratory "Building Loads Analysis and Systems Thermodynamics" (BLAST) program.

Shading of south windows at 43° latitude (Casper, WY; Madison, WI; Buffalo, NY; Manchester, NH)
TABLE 2. CALCULATED HEATING AND COOLING LOADS

<table>
<thead>
<tr>
<th></th>
<th>Heating Load, Btu/Year</th>
<th>Infiltration Loss, Btu/Year</th>
<th>Max. Heat. Load; Btu/Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974 House</td>
<td>57,530,000</td>
<td>35,794,000</td>
<td>36,610</td>
</tr>
<tr>
<td>1980 House</td>
<td>37,260,000</td>
<td>25,600,000</td>
<td>26,770</td>
</tr>
<tr>
<td>Lo-Cal House</td>
<td>24,290,000</td>
<td>18,280,000</td>
<td>20,990</td>
</tr>
</tbody>
</table>

Cooling Load, Btu/Year

<table>
<thead>
<tr>
<th></th>
<th>Infiltration Gain, Btu/Year</th>
<th>Max. Cool. Load, Btu/Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974 House</td>
<td>9,795,000</td>
<td>16,710</td>
</tr>
<tr>
<td>1980 House</td>
<td>10,350,000</td>
<td>15,310</td>
</tr>
<tr>
<td>Lo-Cal House</td>
<td>9,263,000</td>
<td>11,930</td>
</tr>
</tbody>
</table>

Comfort Conditions

For all three houses, the room-air temperature was allowed to vary between 70°F and 78°F. Most people will accept air temperatures a few degrees above or below 72°F, especially when energy is saved.

Winter Performance

The heating analysis of the house can be expressed as:

\[
\text{HEAT INPUT} = \text{HEAT LOSS}
\]

The heat inputs are: (1) internal gains from persons, lighting, refrigerator, range, television, water heating, etc.; (2) solar gains, mainly from windows; and (3) input from heating system which uses fuel or electricity.

The heat losses are made up of: (1) transmission losses through the house shell (ceiling, walls, windows, doors, and floors); (2) air infiltration; and (3) building overheating which must be vented. Since, as yet, demonstration house studies are not completed, the best alternative is to make a thorough engineering analysis, taking into account all energy inputs to the Lo-Cal House. For this purpose, a predictive computer program was used and weather data for Rantoul, Illinois, was selected. The heating degree-days for the test year were 5890. In this analysis, the assumed internal heat gain was equal to 15 kWh per day, which, when added to occupant gains, amounts to 61,000 Btu per day. The computer analysis is summarized in Table 2.

In order to heat the Lo-Cal House for a year, the owner would need to buy (assuming 75% efficiency for gas and oil):

- 239 gallons of fuel oil, or
- 242 therms of natural gas, or
- 7144 kWh of electrical resistance heating.

The owner of a house built to the 1974 standards would have to buy about twice the above amounts each heating season, and the requirements of the 1980 house would be about 50% higher than the Lo-Cal House.

Summer Performance

Because of the extra insulation, the Lo-Cal House gains heat very slowly and the summer cooling load is never high. With the assumed internal heat gain of 61,000 Btu per day, the maximum cooling requirement is about 12,000 Btu per hour in the Rantoul, Illinois, climate. For energy conservation, internal heat gains should be kept as low as possible during warm weather. For example, a large gathering of people in the house would substantially increase the cooling load.

For the computer analysis, the cooling season was considered to be from May 1 through October 31. The total cooling load (including internal heat gains) for the period was computed to be 9.3 million Btu. Assuming that 1 kWh of electricity will deliver at least 6000 Btu of cooling, the energy required for cooling would be about 1550 kWh. At five cents per kWh, the cost for cooling would be $78 for the season. This cost could be reduced by using additional shading of the south windows during August and September, and could be further reduced by using night air cooling when the outdoor air temperature and humidity are suitable.

Cooling System Selection

For the predicted maximum hourly cooling load of 11,930 Btu per hour (Table 2), a central unit with a capacity of one ton or 12,000 Btu per hour would be enough on most days. A larger unit would handle those times when the hourly load is extreme, but the normal operation would be off-and-on, and the humidity would vary and cause discomfort. Better comfort is obtained from a cooling unit which is slightly undersized so that it operates continuously.

If occasional unusually large cooling loads are anticipated, such as a large gathering of people in hot weather, an auxiliary cooling unit might be desirable, or the house could be pre-cooled to a lower temperature to control the short overload.
ALTERNATE DESIGNS

Design B. This incorporates a basement and a fireplace in the basic design. Double sliding glass door units can be used instead of windows.

Design C. This is more appropriate when the street is on the south or east of the lot. The entrance is moved to the end of the house and the garage is relocated.

Design D. This plan shows how the principles may be applied to a two-story dwelling unit.

Variations in Plot Plan.
The principles demonstrated in the design of the Lo-Cal House can be used in the design of all types of housing.

The plot plan shows the use of the various designs in a typical subdivision having a rectilinear street pattern. It is obvious that monotony and sameness need not be a problem.