Attitudes of Visitors to an Earth Sheltered Solar House

K. Kay Stewart
Cora McKown
Jerry O. Newman

Interest in alternative housing forms is increasing in relation to the growing concern about energy (Stobaugh and Yergin, 1979). Two alternative housing forms that might have considerable impact in reducing household energy consumption and costs are solar and earth sheltered homes. However, the wide-spread adoption of solar and earth sheltered designs will depend on consumer and neighborhood acceptance, availability of financing, livability and construction technology.

With proven results of lower fuel costs and increased energy efficiency, earth sheltered housing is rapidly attracting widespread interest among Americans as a desirable economic alternative to the conventional above grade residence (Eccli, 1976; Smay, 1977). With an earthen "blanket" covering the structure, resulting reductions in air infiltration, wind chill, and heat loss account in part for lower fuel usage, thus helping to conserve the nation's conventional fuel resources (Smay, 1977). Since seasonal ground temperatures vary only slightly at 15 feet beneath the earth's surface, maintaining a comfortable interior temperature in an underground dwelling requires far less energy than for an above ground structure (Sterling, 1978). Further, renewable energy resources such as the sun and wood are easily integrated into an earth sheltered system (Manson, 1976).

To date, few research studies have been concerned with the perceived livability of earth sheltered dwellings. Other than performance and attitude studies in institutional settings (such as underground schools), little research has focused on the psychological and behavioral aspects of living underground (Labs, 1976). Thus, there is a need to obtain information regarding people's attitudes about earth sheltered structures. Attitudes regarding design features, comfort, adequacy and other aspects of underground dwellings can provide valuable information to those responsible for the humanistic design of future residential structures. In addition, such information can provide data for lenders and appraisers which can be used in establishing guidelines for the assessment and loan values of earth sheltered homes.

K. Kay Stewart is Associate Professor, Department of Housing, Design and Consumer Resources, Oklahoma State University; Cora McKown is Chairman, Department of Family Management, Housing and Consumer Sciences, Texas Tech University; and Jerry O. Newman is Research Leader, USDA Rural Housing Research Unit, Clemson. *This is a contributing study to the Southern Regional Research Project, S-95, "Quality Housing Environments for Low-Income Rural Families", funded by the USDA Agricultural Experiment Stations under the Hatch Act. Three graduate students contributed much time and energy in the preparation and analysis of the data reported here: Jackie Bell, Carolyn Peck and Ruth Winter.*

Members of the Southern Regional Housing Research Group have conducted multidisciplinary research to identify factors related to the acceptance of alternative housing forms. This article reports the findings from a study of visitors' attitudes toward an earth sheltered, solar heated research prototype built by the Rural Housing Research Unit, in cooperation with Clemson University.

The first objective of this study was to obtain visitors' attitudes toward selected design features of the earth sheltered solar house, including size, spatial arrangement, lighting, privacy, access, expected maintenance costs and energy efficiency. The second objective was to identify the potential market for such housing by analyzing the relationship between the desire to live in an earth sheltered dwelling and visitor characteristics and attitudes about the research prototype.

Description of the House

The house evaluated in this study is the second earth sheltered prototype designed by Newman. The first prototype was redesigned following structural and performance tests and consumers' evaluation of design features (Stewart et al., 1979; McKown and Stewart, 1980). The two bedroom house consists of 1,080 square feet of heated floor space (see Figure 1) and could be built in 1980 for approximately $35,000. The relatively low price keeps the house within the purchasing power of moderate-income families as well as the loan policies of the Farmers Home Administration and other federal lending agencies.

The house is partially embanked in earth on three sides (see Figure 2). The south facing wall and the roof are exposed without earth embankment or cover because initial calculations indicated that the conven-

Table 1—Visitors' Attitudes Toward Selected Characteristics of the Earth Sheltered Solar House

Question	Frequencies (Percent)								
Asked of Total Sample	*Not as Expected*						*Just as Expected*	*Don't Know*	*(N)*
How does this home compare to what you thought an earth sheltered solar home would be like?	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
	12(5)	15(6)	33(13)	48(19)	70(28)	45(18)	25(10)	2(1)	(250)
	Definitely Would Not						*Definitely Would*		
Would you want to live in an earth sheltered solar home if it were the right size for your family?	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
	15(6)	11(4)	15(6)	35(14)	42(17)	40(16)	92(37)		
Asked of Sub-Sample I	*Much Less Light*						*Much More Light*		*(N)*
How does the amount of light (both natural and artificial) in the earth sheltered solar home compare to what you expected?	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
	5(4)	3(2)	9(7)	27(22)	18(15)	44(35)	20(15)		(126)
	Not At All Adequate						*Very Adequate*	*Don't Know*	
How do you feel about the amount of natural light in each of these rooms?	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
Bedroom	1(1)	2(2)	15(12)	19(15)	21(17)	31(25)	36(29)	1(1)	
Living room	1(1)	2(2)	16(13)	17(14)	19(15)	30(24)	39(31)	2(1)	
Kitchen	1(1)	3(2)	10(8)	16(13)	22(18)	32(25)	40(32)	2(1)	
Bathroom	18(14)	8(7)	23(19)	14(11)	13(10)	20(16)	27(21)	3(2)	

tional roof was lower in cost and contained better thermal heat flow properties. The roof contains a 412 square foot solar collector that serves as a supplemental heat source for space heating and provides energy for a new air-type frost-free solar water heater now being tested. Because the integrated collector was low-cost, the importance of both collector size and cost as economic factors was reduced, allowing greater design freedom.

The house is equipped with an air-lock on the door and double glazed windows. The walls have six inch cavities which allow R-19 insulation to be inserted, and the attic is insulated with 12 inches of fiberglass for an insulation value of R-38. A rock bed in the crawl-space provides storage for solar energy and support for the floors.

Because of the general stigma that classifies basements and other below grade spaces as dark, damp and dismal, special emphasis has been placed on moisture proofing and window placement. For ease of assembly the house is prefabricated into pressure-treated, rot-proof wood panels, in contrast to the more common poured concrete or concrete block construction. The grade is sloped away from the house in all directions to prevent surface water from flowing toward the house. A french drain (9 feet deep) ditch installed around the perimeter and below the crawl-space floor intercepts ground water and diverts it away from the house. A plastic moisture barrier placed on the outside of the walls before the soil was bermed around them reduces the possibility of wall condensation. Double glazing on all windows also keeps condensation to a minimum.

Table 1 (Continued)

Question	**Frequencies (Percent)**								
	Not Enough Privacy			*Adequate Privacy*			*Too Much Privacy*	*Don't Know*	
What is your reaction to the amount of privacy the home provides:	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
a. for family members inside the home?	2(2)	12(9)	11(8)	63(50)	29(23)	5(4)	2(2)	2(2)	
b. for family from neighbors?	2(2)	2(2)	6(4)	63(50)	35(28)	8(6)	8(6)	2(2)	
c. from outside noise?	1(1)	0(0)	3(2)	62(49)	36(29)	13(10)	7(6)	4(3)	
	Higher in This Home			*About the Same*			*Lower in This Home*	*Don't Know*	
What would you estimate the annual cost of maintenance and repair to be on this earth sheltered home compared to a conventional home?	*1*			*2*			*3*		
	18(14)			38(31)			67(53)	3(2)	
	No			*Maybe*			*Yes*	*Don't Know*	
Do you think you could obtain financing to build an earth sheltered home?	*1*			*2*			*3*		
	20(16)			40(32)			62(49)	4(3)	
Asked of Sub-Sample II	*Much Smaller Than Expected*			*As Expected*			*Much Larger Than Expected*	*Don't Know*	*(N)*
How does the overall size of the house compare to what you thought it would be like?	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
	12(9)	33(26)	30(24)	26(21)	17(14)	3(2)	1(1)	2(3)	(124)
	Definitely Would Not						*Definitely Would*		
Would an earth sheltered solar home be acceptable in appearance to be built in your community?	*1*	*2*	*3*	*4*	*5*	*6*	*7*		
	5(4)	7(6)	8(6)	12(10)	5(14)	32(26)	46(37)		

The long narrow design allows the rooms to have natural light and virtually eliminates the need for skylights and additional escape routes. This design feature also permits the utilization of passive solar energy. The hallway made necessary by the long narrow floor plan is designed to double as a utility, laundry and storage area. The size of the house can be increased to meet the needs of any size family. As the size of the house increases the design alternatives magnify, allowing one to build a U-shaped structure or include interior courts or atriums. Rear entrances can be installed if one can justify the expense of stairwells. The relatively small size of the house and the operable windows in every room allow easy escape in case of fire. However, the addition of sliding glass or other doors in either or both bedrooms could provide additional access and enhance the psychological atmosphere.

Methodology

The Rural Housing Research Unit of the U.S. Department of Agriculture cooperated with the College of Agricultural Sciences at Clemson University in the design and construction of the earth sheltered solar prototype at Clemson, South Carolina. On three consecutive Sundays in November of 1978 the public was invited to tour the house. The "open house" was publicized via radio, television and newspapers in the surrounding area. Prior to and during the tour, visitors were given written and verbal information about the construction of the house and particular features designed to reduce energy consumption. The instrument for data collection consisted of a questionnaire that included items designed to obtain sociodemographic characteristics of the visitors and their attitudes about the research house, including their desire to live in a

Table 1 (Continued)

Question	Frequencies (Percent)							
	Questionable Idea						*Excellent Idea*	*Don't Know*
What are your impressions of these design features in this home?	*1*	*2*	*3*	*4*	*5*	*6*	*7*	
a. Solar space heating	1(1)	2(2)	3(2)	2(2)	22(18)	33(26)	52(42)	9(7)
b. Solar water heating	1(1)	2(2)	2(2)	2(2)	19(15)	30(24)	57(46)	11(9)
c. Panelized construction	5(4)	5(4)	11(9)	14(11)	16(13)	28(23)	30(24)	15(12)
d. Pressure-treated wood foundation	18(14)	3(2)	6(5)	12(10)	12(10)	21(17)	38(31)	14(11)
e. Earth "insulation"	1(1)	4(3)	4(3)	5(4)	8(6)	31(26)	57(46)	14(11)
	Not At All Adequate						*Very Adequate*	*Don't Know*
Do you feel that access to this earth sheltered home is adequate for:	*1*	*2*	*3*	*4*	*5*	*6*	*7*	
a. bringing in groceries?	5(4)	7(6)	11(9)	13(10)	20(16)	30(24)	36(30)	2(2)
b. moving furniture in and out?	9(7)	13(10)	21(17)	19(16)	19(16)	15(12)	25(20)	3(2)
c. escape in case of fire?	19(16)	18(14)	21(17)	18(14)	13(10)	19(16)	14(11)	2(2)
Given the same amount of floor space, what changes would you make in the floor plan of the earth sheltered home?								
a. None	49(40)							
b. Change room arrangement or add extra features	22(18)							
c. Reduce the size of bedrooms and increase living area	21(17)							
d. Three smaller bedrooms	10(8)							
e. More storage and less living area	8(6)							
f. Other	14(11)							

similar home at some future time. The questionnaire was a revision of an earlier questionnaire that had been used to evaluate the first prototype.

The sample for the study was drawn from persons who visited the prototype during the open house tours. Thus, it is strictly a volunteer sample composed of persons who were sufficiently interested to attend the open house. Generalizations should not be made beyond this limitation. A questionnaire was given to every fourth person, excluding minors. In order to limit the length of the questionnaire, two forms were used. Both forms contained identical questions about characteristics of the visitors and their desire to live in a home similar to the prototype; however, the two forms asked for reactions to different aspects of the house. A total of 250 questionnaires were completed and returned for analysis—126 of form one and 124 of form two. This was approximately a 40 percent return. The characteristics of the respondents in the two sub-samples did not differ significantly, so no distinction is made between the two sub-samples when discussing characteristics of respondents.

Results

Characteristics of the Sample

Ages of respondents ranged from 20 to over 65 years, with over half of the sample in the 25 to 44 year age group. This age group is most likely to contain persons who are potential home buyers. Slightly more than half of the respondents were male and over three-fourths were married. The education level ranged from one year of high school to doctoral degrees. Less than 10 percent of the sample had not graduated from high school and over half had at least some college training. The largest percentage of the sample came from towns of 1,000 to 10,000 in population and approximately one-third came from rural areas. The annual income of the respondents ranged from $5,000 to over $35,000, with more than 50 percent indicating an annual income in excess of $20,000. Over 80 percent of the sample had never visited an earth sheltered home before this visit and only five respondents had ever lived in an earth sheltered home. Approximately one-half of the sample felt that the energy crisis was "definitely real", and an additional 30 percent thought that the energy crisis was "to some degree real".

Attitudes Toward Selected Aspects of the Earth Sheltered Solar House

The first objective of this study was to describe visitors' attitudes toward the earth sheltered house. Most of these attitudes were measured on a seven point Likert type scale, with "one" being the most negative response and "seven" being the most positive response (see Table 1). Approximately one-fourth of the sample indicated that the earth sheltered house was close to what they had expected, while the remainder of the sample was either not sure what to expect or was surprised by what they found in the house. Over one-third stated that they "definitely would" want to live in an earth sheltered solar home if it were the right size for their family. The majority felt that the amount of light (both natural and artificial) in the house was more than expected and over 70 percent also indicated that the amount of natural light was "adequate" to "very adequate" in all rooms except the bathroom. As can be seen in Figure 1, the bathroom was located to the back of the house and thus was devoid of natural light.

Responses to how the overall size of the house compared to expectations were quite varied, but over one-half felt that the house was smaller than expected. Twenty-one percent were neutral in response to the size of the house and only 17 percent thought the house was larger than expected. The single entrance to the house was of concern to the visitors, as illustrated by the fact that nearly half of them indicated that access was not adequate for escape in case of fire. Over one-half of the visitors concluded that the house provided "adequate privacy" for family members within the house and for the family from its neighbors and outside noises. In fact, nearly one-third of the individuals indicated that the house provided more than adequate privacy from neighbors and outside noises. The reduced contact with the outside may well be a constraint to housing consumers and must be offset by other advantages offered by earth sheltered designs.

When asked to indicate how they thought mainte-

nance costs of the earth sheltered house would compare to a conventional house, over half thought the costs would be lower in the earth sheltered house, while only 14 percent thought maintenance costs would be higher because of the solar equipment, with which they may not have been familiar. Nearly two-thirds of the respondents were sure they could obtain financing to build or buy an earth sheltered house and an additional 32 percent thought they might be able to obtain financing. Because of the high educational and income levels of the sample, this response may be more reflective of a general feeling about the ability to obtain mortgage financing for any house than of the specific experience or attitude concerning their ability to obtain mortgage financing for an earth sheltered house. Lenders are still hesitant at this point in time to lend money for an earth sheltered or underground house unless the borrower has a very good credit rating (McKown et al., 1981).

Over one-third of the respondents indicated that they thought an earth sheltered house would be sufficiently acceptable in appearance to be built in their community, but approximately one-fourth did not think their communities would accept such houses. In response to specific design features of the house, approximately three-fourths of the respondents indicated that the solar space heating, solar water heating and the use of earth as an "insulator" were good or even "excellent" ideas. However, visitor response to the use of pressure-treated wood foundation and panelized wood construction was much less favorable. Only about one-fourth of the respondents indicated the use of pressure-treated wood and panelized construction were "excellent" ideas and nearly one-third indicated that these were to some degree "questionable" ideas.

Overall, the response to the earth sheltered solar prototype was quite favorable. The features that caused the most concern were the use of pressure-treated wood for the foundation, panelized construction, and the lack of egress from the rear of the house in case of fire. The response of these visitors to the use of solar equipment for space heating and water heating was quite positive as was the reaction to the earth sheltering concept. The visitors seemed confident that they could obtain financing for an earth sheltered house; however, their actual experience with lenders might be less positive were they to actually apply for such funding.

Respondents were asked to indicate changes that might be made in the floor plan or other design aspects to better meet their needs without increasing the overall floor space. Forty percent of the respondents did not want to make any changes in the plan for the earth sheltered house but 18 percent wanted to change the room arrangement or add extra features such as a fireplace and additional storage. The most frequently mentioned change in the spatial arrangement related to increasing the size of the living area and reducing the size of the bedrooms.

Desire to Live in an Earth Sheltered House

The second objective of this study was to analyze the relationship between the desire to live in an earth sheltered house and visitors' characteristics and attitudes toward the research house. It was hypothesized that age, income, education, sex and marital status, along with attitudes about selected aspects of the house, would affect the desire to live in a similar house if it were the right size for a respondent's family. This hypothesis was tested by stepwise multiple regression analysis. The two sub-samples were analyzed separately because different attitudes were measured for each group. However, the measurement of sociodemographic characterisitcs for the two groups were the same. All of the respondent characteristics and the variables that were statistically significant at the .10 level or less were retained in the model. The final model for the two sub-samples is shown in Table 2.

The regression of the desire to live in an earth sheltered house on the sociodemographic characteristics and attitudes of visitors had a small but statistically significant R^2, indicating that the variables shown in the table for sub-sample I explained about 20 percent of the variance in the desire to live in such a home. It was not expected that all of the variables influencing one's desire to live in an earth sheltered home had been captured in this model so the small R^2 was expected. The objective was to identify the variables which were more strongly related to a positive feeling about living in an earth sheltered house, and

this can be determined by the size of the standardized betas. A larger standardized beta indicates that a particular variable has greater influence than does another variable.

For sub-sample I, the evaluation of the adequacy of lighting in the house had the strongest relationship with the respondent's desire to live in such a home (beta = .2518). Those who gave higher evaluations to the adequacy of the light levels were more likely to want to live in an earth sheltered house. The second strongest relationship was with marital status. Married persons expressed a desire to live in a similar home more so than single persons. Two other variables were found to be statistically significant: the desire to live in an earth sheltered home was greater for those who expected the cost of repair and maintenance to be lower for the earth-integrated house and for those whose education levels were higher.

The regression analysis for sub-sample II is also shown in Table 2. For sub-sample II only three variables were found to be related to the desire to live in an earth sheltered home. None of the sociodemographic characteristics of this sub-sample were significantly related to the desire to live in an earth sheltered house. The desire to live in such a house was related most strongly to the perceived acceptability of the house in the respondent's community (beta = .3572). The second most important variable was the evaluation of the accessibility of the design for bringing in groceries or furniture and for escape in case of fire.

Table 2—Multiple Regression of Desire to Live in an Earth Sheltered Home on Selected Visitor Characteristics and Attitudes About the Research House

Sub-Sample I			
Variable	**Coefficient**	**Beta**	**F Ratio**
Evaluation of amount of light	.8084	.2518	6.4
Marital status	1.1449	.2442	6.2
Expected cost of repair and maintenance	.5349	.2124	4.8
Education	.3361	.2046	4.1
Constant 1.0654			
Reduced model R^2 = .204			
F = 4.02			
df = 3 & 93			
p <.01			

Sub-Sample II			
Variable	**Coefficient**	**Beta**	**F Ratio**
Acceptability of this house in your community	.3878	.3572	16.2
Accessibility	.1267	.3255	14.3
Evaluation of solar water and space heating	.1266	.1514	3.0
Constant .2574			
Reduced model R^2 = .348			
F = 16.5			
df = 3 & 93			
p <.01			

The third most influencing attitude was the respondents' evaluation of the solar water heating and space heating utilized in the research house. These three variables explained approximately 35 percent of the variance in the desire to live in an earth sheltered house if it were the right size for a respondent's family.

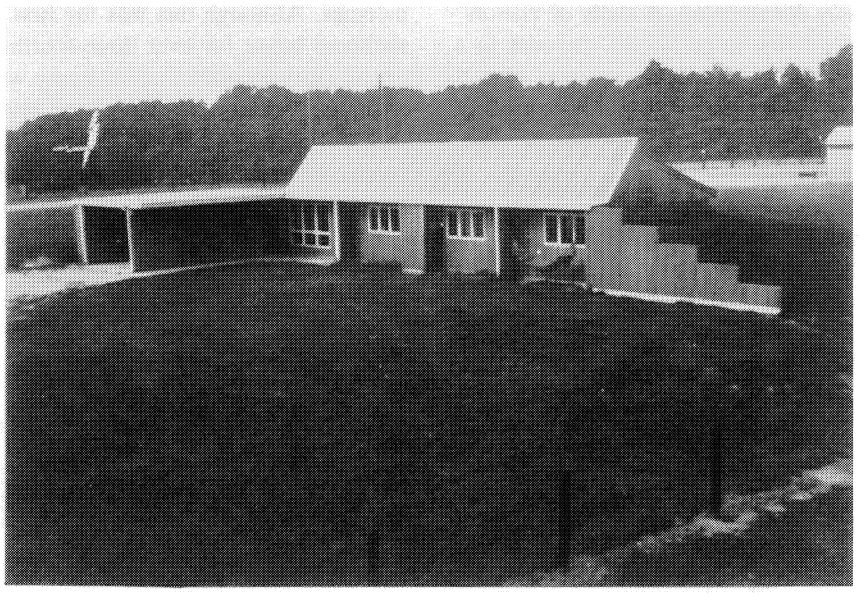


Figure 1—Photographs of the Earth Sheltered Solar Prototype

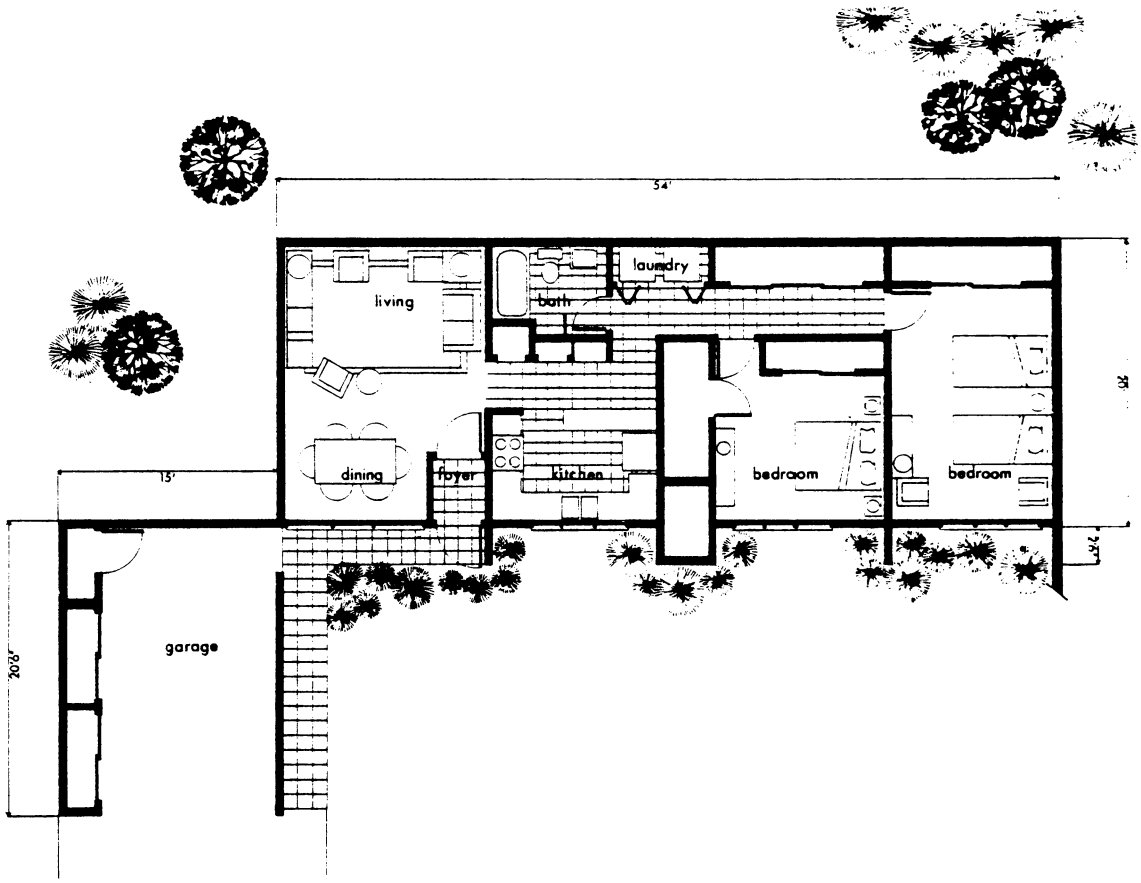
Conclusion

The research reported here is experimental in nature. Visits to an "open house" have been used as a marketing device for many years, but adapting a research methodology to obtain systematic design input has not been widely documented. A study of visitors' acceptance offers a "first impression" response to a particular house type rather than an analysis of that house over a period of time which is provided in post-occupancy evaluation. Both research approaches provide needed information. Acceptance studies are especially applicable for emerging housing forms. As concern for energy efficiency increases, the need for data related to design acceptance is intensified. The "first impression" does not document how well the design functions; rather, it provides information about the acceptance of alternative house forms and new directions in the housing market.

The majority of the visitors to the earth sheltered solar house were well educated with moderate to high incomes. Although this was the first visit to an earth sheltered house for over three-fourths of the sample, the majority reported that the house was fairly close to what they had expected. It may be that the visitors who responded to the "open house" invitation were concerned about energy and were somewhat aware of the principles of earth sheltered designs.

The visitors responded very positively to the solar space heating and water heating features of the house

Figure 2—Floor Plan of the Earth Sheltered Solar Prototype



as well as the earth sheltered concept. They were optimistic about the energy saving potential of this prototype and about their ability to obtain financing for such housing. They also gave high ratings to the adequacy of natural light in this open facade earth sheltered plan. The lack of natural light in the bathroom, which was on the back side of the plan, was of concern to the visitors as was the limited egress in case of fire.

Suggestions for design changes in the next generation prototype included: (a) enlarging the living area while making the bedrooms smaller, (b) adding extra features such as a fireplace that could serve as the back-up heat source, (c) altering the room arrangement, and (d) putting a skylight in the bathroom.

Three attitudes were found to be strongly related to the visitors' desire to live in a similar earth sheltered house: (a) their perception of the acceptability of such a home in their community, (b) their evaluation of the accessibility of the design for convenient ingress and egress, and (c) their evaluation of the adequacy of lighting. The findings suggest that these are important aspects to be considered by architects and designers of future earth sheltered prototypes. Concern with community acceptance of the earth sheltered dwelling is probably reflective of the predominantly suburban sample. An earlier study of housing preferences indicated that consumers would like to "trade-up" in the housing market but were unwilling to make marked departures in design (McKown, 1975). This concern with community acceptance is also reflective of marketability, appraisal and zoning issues surrounding earth sheltered designs. Those who are marketing earth sheltered homes may want to address the subject of acceptability within communities and develop programs to inform potential home buyers of the advantages of this house form. Design features that were found to be unacceptable can be altered to increase acceptability.

Additional earth sheltered prototypes need to be built to increase the exposure of the public to this alternative and to overcome some negative stereotypes held by those who have never experienced an earth sheltered house. Acceptance studies of the prototype will provide information needed by architects and designers who want to meet consumer needs and desires. Acceptance studies also provide an opportunity for prospective home buyers, lenders and appraisers to become more familiar with a variety of earth sheltered designs, and perhaps can encourage the development of more positive attitudes toward them.

References

Eccli, E., 1976. *Low-Cost, Energy Efficient Shelter*. Emmaus, PA: Rodale Press.

Labs, K., 1976. "The architectural underground." *Underground Space* 1 (July/August): 135-156.

Manson, D., 1976. "Equity requirements of earth covered buildings and instruments of remedy." Pp. 37-42 in *The Use of Earth Covered Buildings*. Washington, D.C.: U.S. Government Printing Office.

McKown, C., 1975. "Social factors related to housing selection." *Housing Educators Journal* 2 (January): 11-15.

McKown, C., A. W. Gustafson, and K. Hobbs, 1981. "Policies and procedures for funding alternative housing." Lubbock, TX: Unpublished manuscript.

McKown, C. and K. Stewart, 1980. "Consumer response to design criteria of an earth sheltered dwelling." *Underground Space* 5 (January/February): 293-295.

Smay, V. E., 1977. "Underground houses." *Popular Science* 210 (April): 84

Sterling, R. (ed.), 1978. *Earth Sheltered Housing Design*. Minneapolis, MN: Underground Space Association.

Stewart, K., C. McKown, and C. Peck, 1979. "Consumer attitudes concerning an earth sheltered house." *Underground Space* 4 (July/August): 11-15.

Stobaugh, R., and D. Yergin, 1979. *Energy Future*. New York: Random House.