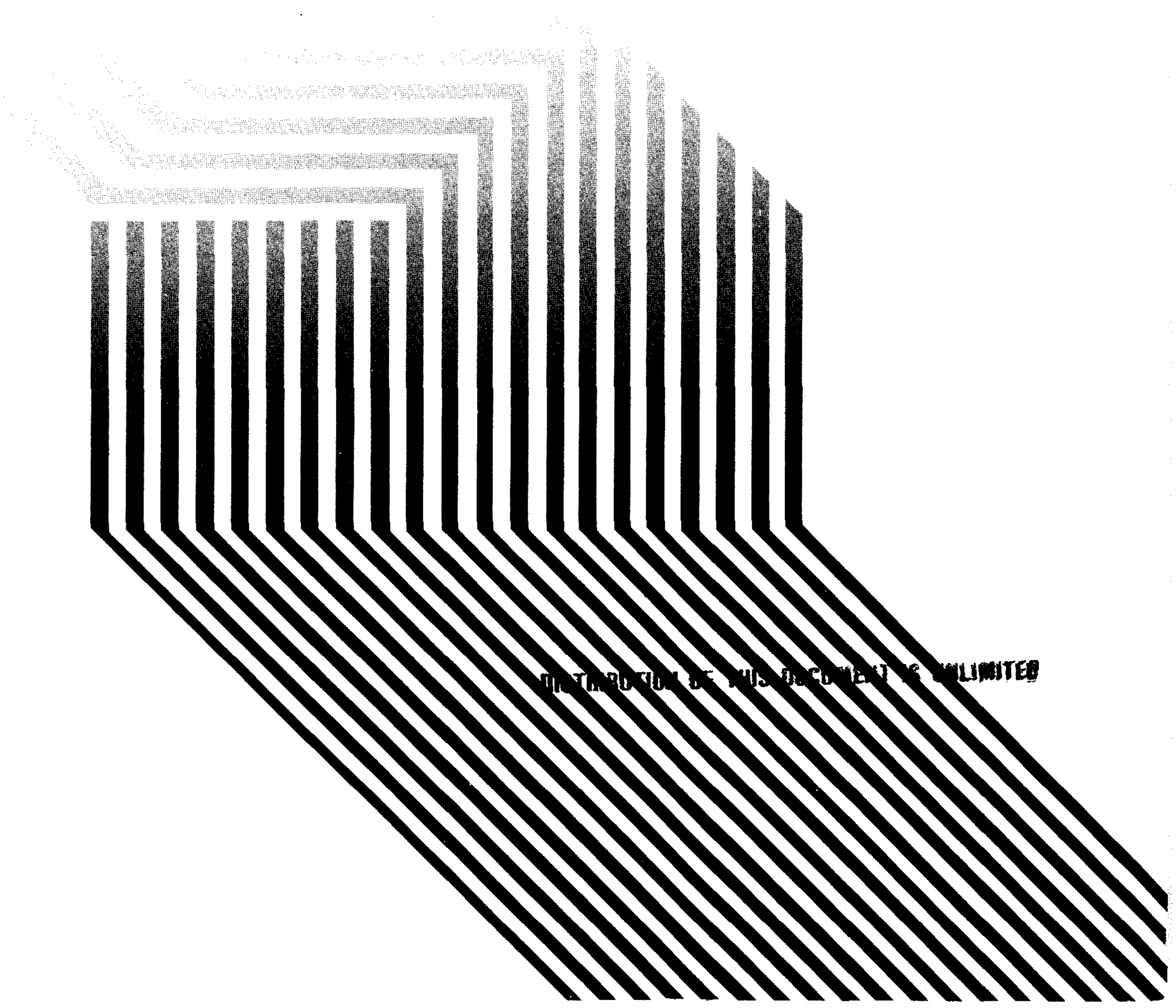
PASSIVE SOLAR HOMES
A NATIONAL STUDY



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Preface

In keeping with the national energy policy goal of fostering an adequate supply of energy at a reasonable cost, the United States Department of Energy (DOE) supports a variety of programs to promote a balanced and mixed energy resource system. The mission of the DOE Solar Buildings Research and Development Program is to support this goal by providing for the development of solar technology alternatives for the buildings sector. It is the goal of the Program to establish a proven technology base to allow industry to develop solar products and designs for buildings that are economically competitive and can contribute significantly to building energy supplies nationally. Toward this end, the Program sponsors research activities related to increasing the efficiency, reducing the cost, and improving the long-term durability of passive and active solar systems for water and space heating, cooling, and daylighting applications for buildings. These activities are conducted in four major areas: Advanced Passive Solar Materials Research, Collector Technology Research, Cooling Systems Research, and Systems Analysis and Applications Research.

Advanced Passive Solar Materials Research — This activity area includes work on new aperture materials for controlling solar heat gains and for enhancing the use of daylight for interior lighting. It also encompasses work on low-cost thermal storage materials that have high thermal storage capacity and can be integrated with conventional building elements, and work on materials and methods to transport thermal energy efficiently between any building exterior surface and the building interior by non-mechanical means.

A Product of the
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Collector Technology Research — This activity area encompasses work on advanced low to medium temperature (up to 180°F useful operating temperature) flat plate collectors for water and space heating applications, and medium to high temperature (up to 400°F useful operating temperature) evacuated tube/concentrating collectors for space heating and cooling applications. The focus is on design innovations using new materials and fabrication techniques.

Cooling Systems Research — This activity area involves research on high performance dehumidifiers and chillers that can operate efficiently with the variable thermal outputs and delivery temperatures associated with solar collectors. It also includes work on advanced passive cooling techniques.

Systems Analysis and Applications Research — This activity area encompasses experimental testing, analysis, and evaluation of solar heating, cooling, and daylighting systems for residential and nonresidential buildings. This involves system integration studies, the development of design and analysis tools, and the establishment of overall cost, performance, and durability targets for various technology or system options.

This report is an account of research conducted in the Systems Analysis and Applications Research area concerning the Class C performance monitoring effort. The Class C approach attempted to determine as much as possible about the performance of a large number of single-family passive solar homes, both new and existing. Information on overall performance and owner satisfaction was gathered through technical and nontechnical audits administered by trained auditors. Data were collected for 335 homes across the country in 1979-80. This publication, *Passive Solar Homes: A National Study*, summarizes the results of this program.

Acknowledgments

This document was prepared under the auspices of the Passive Solar Heating and Cooling Division, Office of Conservation and Renewable Energy, U.S. Department of Energy. Contributing to this report were the Memphremagog Group; Market Facts, Inc.; Total Environmental Action; SERI; and the four Regional Solar Energy Centers. Beth Sachs of the Memphremagog Group and Rob deKieffer of SERI's Building Systems Branch provided major assistance in compiling the document.

Contents

Executive Summary

This study highlights valuable findings on the thermal comfort and livability of passive solar homes. These buildings are a sample of 335 homes that incorporate early passive solar designs.

The data collection effort consisted of a performance audit conducted by trained auditors and an occupant questionnaire completed by the passive solar homeowners on their perceptions, experiences, and demographics. The questionnaire and audit technique coupled with utility bills were used to establish a data base of both quantitative and qualitative information on the performance of these passive solar homes.

For these selected homes, direct gain was the most common passive heating system type and the direct gain storage floor was the most common primary thermal storage technique. Natural ventilation was the dominant passive cooling system. The homes were generally well insulated as demonstrated by the low value of the average estimated net heat loss. Overall, the buildings were not extraordinary in terms of such variables as total purchased energy use or estimated infiltration, nor did the occupants keep the temperatures lower than the average for nonsolar homes. When these and other variables for the passive solar homes are viewed in the aggregate, however, these buildings are notably different from nonsolar homes.

The buildings do not have substantially larger aperture-to-floor ratios than nonsolar buildings: more than 60% are below 0.15. Placement of windows, rather than their number, appears to differentiate these homes from their nonsolar counterparts. Rather than having more windows, many of these homes have windows that are positioned to take best advantage of the sun. Another finding is that the use of wood as a primary heat source is more widespread than indicated in other studies, with 46% of the homeowners surveyed using wood as their major "conventional" heat source.

The homeowners in this study are considered early adopters of passive solar technology. The results presented in the study, therefore, reflect the subjective views and reported experiences of this select population. As would be expected of technological innovators (see Rogers and Shoemaker 1971), these homeowners tend to be younger, better educated, and have higher incomes than homeowners in general. The majority of them first got the idea to purchase a solar home from books, magazines, and individuals. They cited books and solar seminars as the most valuable information sources for learning about solar design.

These homeowners cited energy cost savings as the primary reason they selected a passive solar home. The majority initially underestimated how well their passive systems would perform and were pleased with the actual performance. Even respondents who did not feel their passive systems performed as expected were very satisfied. This positive attitude may in part reflect the enthusiasm of these innovators for renewable energy technologies. About half of the sample stated that, having lived in a passive solar home, they would not again buy a house without passive solar features.

The experiences of the homeowners highlight numerous minor problems with the comfort of these early designs. Although problems identified in this study were not commonly regarded as very serious by this population, they warrant consideration in future research. These problems include overheating, keeping glass clean, condensation on windows, and glare. Manual components, such as movable insulation, also merit examination: many homeowners found them inconvenient. Additional areas for significant research include thermal storage, heat distribution, humidity control, integration of mechanical systems, and operation and maintenance.

Introduction

Background

Over the last decade increasing numbers of both new and renovated homes have included elements of passive solar design. South-facing glazing, sunspaces, greenhouses, and thermal storage systems have been incorporated into homes with a variety of architectural styles. How well do the passive systems in these homes work? Are the homes comfortable? Is it difficult to maintain homes with passive solar features? Is their construction more expensive than their energy savings warrant?

To answer such questions, the U.S. Department of Energy (DOE) developed a program in the late 1970s to evaluate passive solar performance in residences. The Performance Monitoring and Evaluation Program established three levels of monitoring: (1) Class A — to examine heat transfer processes, develop and validate algorithms, and analyze new materials and component performance in full-scale facilities; (2) Class B — to determine passive solar contribution to space-conditioning requirements; and (3) Class C — to determine overall building thermal performance and occupant satisfaction. The Class A monitoring was performed in 4 unoccupied buildings, Class B involved about 100 occupied homes, and Class C, although intended for 2000 occupied homes, actually included only 421. This report summarizes findings of the Class C effort.

The Class C effort developed in 1979 (Memphremagog and SERI 1980) focused on aspects of performance as perceived by the occupants, such as heat distribution, overheating, and thermal comfort. Information on overall house performance is based on a full year of fuel consumption records. The original plan for Class C proposed that 400 homes would be evaluated each year for 5 years, resulting in a data base of 2000 buildings. This plan called for updating performance data annually so that changes in the state of the art could be determined over time. Because of programmatic changes at DOE, however, only 321 buildings were evaluated in the first year, 100 in the second year, and none in subsequent years.*

*Twenty of the audited homes are included in the SERI document *Passive Solar Homes: 20 Case Studies* (SERI/SP-271-2473, available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Stock No. 061-000-00643-5). A description of each home and its passive system, a photo, floor plans, a section, specifications, performance data, and cost of energy and construction data are provided.

The primary objective for the Class C program was to collect data on the thermal performance of passive solar homes; however, additional objectives were added to the program by the four then-existent Regional Solar Energy Centers (RSECs). One such objective was to collect marketing data that would aid the RSECs in their programs to facilitate use of solar energy in their respective regions.

Although noninstrumented data do not provide information about individual building or system performance that is as precise or scientifically accurate as that supplied by Class A or B data, they are useful in the aggregate. The design of the Class C program allowed researchers to address a broad range of technical issues and occupant experiences. The larger data base can assist researchers in drawing well-founded conclusions about such factors as the relative performance of specific systems under different climatic and use conditions and the average performance of passive solar homes in general. Cost and energy consumption data provide feedback on how well passive solar cost and performance goals were met. The frequency and severity of problems encountered by owners in existing passive solar homes indicate areas where further research and development may be necessary.

Implementation

The Class C Residential Buildings Monitoring Program originally planned for on-site performance evaluations of approximately 100 passive and hybrid solar homes in each of the four regions of the nation served by the four Regional Solar Energy Centers (Northeast Solar Energy Center, Southern Solar Energy Center, Mid-America Solar Energy Complex, and Western Solar Utilization Network). Trained auditors were to collect data at each house.

Of the 400 Class C audits planned for the first year of the program (1979-80), 321 were actually completed. This report addresses only the first year of the Class C study. In 1980, data from the first year were analyzed, and an additional 100 audits were conducted in the Northeast region only. The Northeast Solar Energy Center published a report on its second year program (Saras and Duffy 1981). Subsequently, however, further Class C activities were discontinued. Other programs have since conducted similar studies, some of which are patterned directly after the original one. During 1980-81, 60 Class C audits were conducted in California (Mahajan et al. 1983) and other university, state, and local activities have continued to 1985 (Zentner 1981; Katz 1983; Case 1983).

The Class C program was designed and managed by several organizations — the four RSECs, the Solar Energy Research Institute (SERI), and The Memphremagog Group (TMG). Market Facts, Inc., assisted SERI, TMG, and the RSECs in designing, pretesting, and revising the occupant questionnaire. TMG, in consultation with the RSECs and Total Environmental Action (TEA), designed the thermal audit form completed by the auditors. Each of the four RSECs was responsible for selecting the auditors as well as the sites for its region. TMG trained all of the auditors and provided them with on-call technical assistance. The auditors gathered descriptive and technical information on an audit form and asked the occupants to complete a questionnaire. The two forms (technical audit and questionnaire) are provided in Appendixes A and B.

Data from the technical audits and occupant questionnaires were analyzed separately. Market Facts and the RSECs were responsible for the regional analysis of the occupant data (Market Facts 1981a-d; Saras 1981). SERI was responsible for the national analysis. TMG analyzed the national auditor data. TEA conducted a separate technical study comparing measured energy use with design tool predictions (Fanning, Temple, and Duffy 1981). Because these analyses were conducted by different groups, the approach and style of presenting the data varied somewhat. TMG, under contract to SERI, coordinated these program efforts.

Site Selection

The homes included in the Class C program were selected with the end use of the data in mind. DOE and SERI wanted a large, diverse, purposive* sampling of homes throughout the country to determine the typical performance of passive/hybrid solar homes and their impact on national energy consumption.

Two levels of site selection criteria were established: minimum and preferred. All sites included in the study met the following minimum criteria:

- The system must have been fully operational and the home occupied for at least one full year
- A full year of complete energy consumption records must have been available.

The four RSECs were interested in using study results for technical assistance, public information, and commercialization activities. From among the sites meeting the minimum criteria, each RSEC selected sites meeting its own criteria. The RSECs put considerable effort into defining their sampling criteria, which may prove valuable for future research designs. Appendix E presents an example of criteria used by the Northeast Solar Energy Center.

The Class C program planned that each RSEC would develop a pool of potential sites that met the minimum criteria, and then apply its preferred criteria to select the sites for the actual audits. The RSECs used many techniques to develop lists of potential passive solar home sites, including the following:

- Searches for passive solar homes in earlier surveys of solar buildings
- Mail-back coupons in solar publications
- Solicitations in RSEC newsletters
- Requests for lists from State Energy Offices
- Requests to state and local chapters of the American Solar Energy Society
- References from architects and engineers
- References from solar homeowners.

In all regions, it proved more difficult than anticipated to develop a pool of potential sites that met the minimum criteria perhaps because of the scarcity of passive solar homes at that time. As a result, almost all sites that met the minimum requirements were audited regardless of whether they met the preferred criteria.

Although 100 sites were identified for each region, 100 acceptable audits were not completed in each region for two reasons. First, the auditing process began while some sites were still being selected. A few sites had to be rejected when the auditors realized they did not meet even the minimum criteria. The lateness of these discoveries in the data collection process usually precluded identifying an alternative site. Second, some audits were so incomplete that they were unusable. As a result of these difficulties, the number of audits used in the study varied from region to region.

The report is organized into two sections: first, key findings from the audit forms completed by the trained auditors on-site are presented. These findings describe the types of passive solar homes and systems in the Class C sample, their energy use characteristics, and their building energy performance. The second part of the report presents key findings from the occupant questionnaire completed at the time of the audit. These findings deal with factors affecting the owners' purchase of a passive solar home, information sources, perceived contribution of the system to total heating needs, problems encountered, and owners' overall satisfaction with their passive solar homes.

*A purposive sample is a nonrandom sample designed for a specific purpose — in this case, passive solar homeowners selected because their homes met certain physical criteria and they had at least a year's experience in living in a home with passive solar features.

Audit Findings

Introduction

Audits were completed and usable for 321 homes; Table 1 lists the number of audited sites by region and state. Auditors were provided with instructions (Appendix C) and a set of reference charts (Appendix D).

The audit form shown in Appendix B, was designed to elicit the following information:

- The general setting of the house, including neighborhood (suburban, urban, rural), solar access, wind exposure, and local weather
- A thermal description of the building, detailed enough to calculate overall heat loss and gain
- Sources and estimated quantities of internal heat gains, such as those from appliances, furnaces, water heaters, lights, and occupants
- A detailed description, including sketches, of all the passive solar heating and cooling systems
- Sources and use of auxiliary energy, including details on equipment and operation, and fuel or utility bills for at least one year.

Each RSEC selected auditors with technical backgrounds and familiarity with passive solar energy systems. TMG held two-day training sessions in each region, involving a total of approximately 20 auditors. Both the training program and the audit form were designed to promote consistency in data collection. TMG provided on-call consultation to auditors in the field, further ensuring that the forms would be completed uniformly. The auditors were also responsible for seeing that the occupants completed their questionnaire. The auditor obtained energy-use data (typically utility bills) from the occupant during the audit or from the supplying utilities at a later date. A typical audit took three hours to complete. Because the audit involved hundreds of data points about the homes as well as drawings and energy consumption data, only the results of the most important items have been included in this report.

Table 1. Location of Audited Homes

Northeast		South		Mid-America		West	
State	N[a]	State	N	State	N	State	N
Connecticut	5	Alabama	4	Iowa	5	Arizona	6
New Hampshire	10	Arkansas	6	Illinois	13	California	1
Massachusetts	15	Delaware	1	Kansas	8	Colorado	14
Maine	6	Washington DC	2	Michigan	9	New Mexico	15
New Jersey	8	Florida	6	Minnesota	3	Nevada	2
New York	10	Kentucky	7	Missouri	7	Oregon	11
Pennsylvania	31	Lousiana	4	Ohio	9	Utah	5
Rhode Island	2	Maryland	6	South Dakota	10	Washington	9
Vermont	10	Mississippi	5	Wisconsin	8	Wyoming	3
		North Carolina	12				
		Oklahoma	7				
		South Carolina	4				
		Tennessee	5				
		Texas	6				
		Virginia	7				
		West Virginia	4				
Total N	97		86		72		66

[a]N = number.

Selected Building Characteristics

Operational Date

Table 2 shows the date each home was completed or renovated. Almost all of the 307 sites for which these data are available were built or renovated sometime during the five years preceding the survey. More than half of the passive systems had been in operation for only one year before the survey was conducted. Many occupants commented that they anticipated improvements to their passive systems, such as the installation of movable insulation, which were not in place at the time of the audit. Both this fact and the inexperience of the occupants in operating their systems should be taken into account when interpreting results and making recommendations.

Table 2. When Home was Built or Retrofitted

Year	Sites %	Sites N
Prior to 1974	2	(5)
1974	1	(3)
1975	2	(6)
1976	7	(20)
1977	14	(44)
1978	23	(70)
1979	43	(133)
1980	8	(26)
Totals	100	(307)
Missing data		(14)
Total N		(321)

Data from audit, item 8.

Solar Access

Most sites had good or slightly restricted solar access. Slight restriction means that the aperture may be slightly shaded during a winter day but that 70% to 90% of the glazing is unobstructed during the heating season. Although slightly restricted access is not ideal, this level of solar access will generally contribute to adequate performance. Auditors categorized solar access using the method outlined in the Instructions to Auditors (Appendix C). Table 3 shows solar access data for all sites. The mean level of solar access did not vary between regions or between new houses and retrofits.

Floor Area and Aperture Area

For the purposes of the study, floor area included any areas that were heated or cooled to within 10°F (5.6°C) of the temperature in the main living space. Thus, rooms that were closed off in the winter were not included, although basements, workshops, and other areas were included if the temperature fell within the 10°F (5.6°C) range. This definition of floor

Table 3. Degree of Solar Access

Solar Access	Homes %	Homes N
Open	59	(188)
Slightly restricted	33	(97)
Restricted[a]	8	(25)
Totals	100	(310)
Missing data		(11)
Total N		(321)

Data from audit, item 15.

[a]Shaded for at least 2 hours on a winter day.

area differs from a commonly used one that defines floor area by whether a space is "finished." The definition used in this report is appropriate for thermal normalization, however, and is similar enough for comparison with the definition used by the National Association of Home Builders (NAHB). Such comparison figures for the size of nonsolar homes are taken from NAHB data on homes built in the year 1979, the median date of construction or retrofit for the audited passive solar homes.

Table 4 presents data on floor area of the audited homes and of average nonsolar homes. The mean heated floor area of the sites was 2136 ft^2 (192 m^2). Sites in the Mid-America region were significantly larger than those in the rest of the country. Compared to those of other single-family homes in the United States, floor areas of the audited homes were larger than average. This finding is probably related to the fact that 76% of the homes are custom-built, which tend to be larger than conventionally built homes.

Data were collected on the total aperture area — the net total area of all south-facing glazing — and on the glazing areas associated with the dominant and secondary passive systems in each home. Table 5 shows the data for aperture area, and Figure 1 shows the aperture-to-floor-area ratio. The mean aperture-to-floor-area ratio for all sites was 0.14. This ratio in each region is close to the national mean except for the Western region where it is considerably higher (0.17).

The aperture-to-floor-area ratios are quite low considering the amount of solar contribution and comparison with a conventional construction. The estimates of floor area made by the occupants during site selection excluded basements, which were included in the figures reported by the auditor. The apparently low ratios, combined with other information found in this study, reflect the fact that most of the audited homes fell into the low-aperture/low-mass/well-insulated category of solar homes rather than the high-aperture/high-mass category. One major factor contributing to the low ratios is the number of homes in the sample that used direct gain for passive solar heating.

Table 4. Average Floor Area

Region	Audited Passive Solar + ft² (+ m²)	All 1979 Homes from NAHB[a] + ft² (+ m²)	Variance + ft² (+ m²)
Northeast	1905 (171)	1803 (162)	102 (9)
South	2160 (194)	1644 (148)	516 (46)
Mid-America	2482 (223)	1720 (155)	762 (68)
West	2160 (194)	1697 (153)	463 (41)
All sites	2136 (192)	1714 (154)	422 (38)

Data from audit, item 21.

Numbers in parentheses are in square meters. Floor area includes any areas that were heated or cooled to within 10°F (5.6°C) of the temperature in the main living space.

[a]Study involved 63,754 participants.

Table 5. Average Aperture Area

Aperture	ft²	(m²)
Total south aperture	281	(25)
Dominant system[a]	197	(18)
Secondary system[b]	58	(5)

Data from audit, item 31. Numbers in parentheses are in square meters.

[a]The primary passive solar system type in the building.

[b]Additional systems that supplement the dominant system.

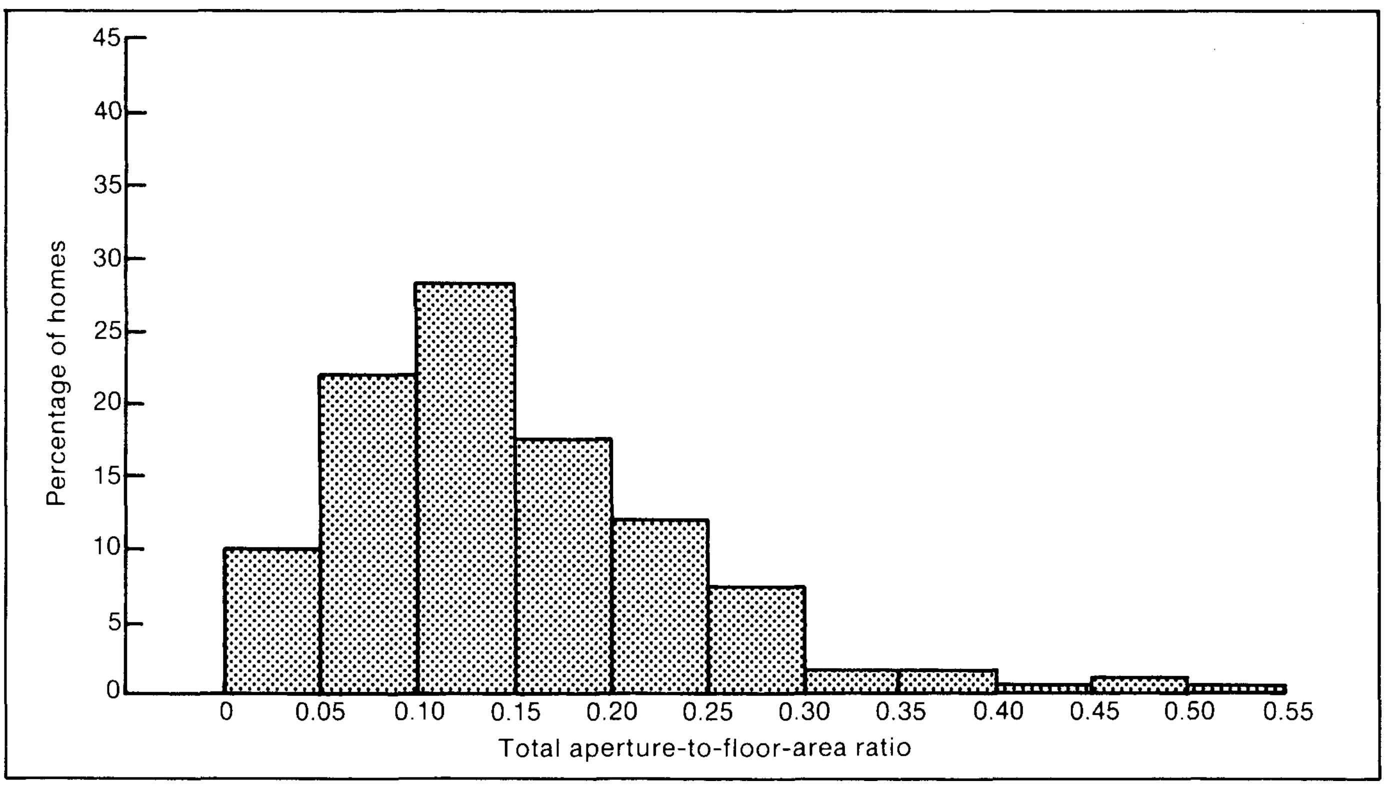

Figure 1. Aperture-to-floor-area ratio

Types of Heating and Cooling Systems

Solar Heating and Cooling System Types

Direct gain was the most common passive solar heating system; three-quarters of the homes had direct gain systems. The direct gain classification includes both south-facing window systems and sunspace systems that are part of the living space and not separated from the rest of the living space by a storage wall. The developers of the Class C program had intended to compare the data compiled on the different system types; however, such comparisons were precluded because the direct gain systems so outnumbered the others. Table 6 presents the data on frequency of passive solar heating system types and Figure 2, the schematics used to classify systems.

Information was also obtained on the type of thermal storage mass in each home, with floor slab being the most common type (32%). Appendix D describes in detail the storage patterns, and Table 7 displays the frequency of different configurations. Not all homes had additional thermal storage mass. Various heat storage systems were used; the most common was mass flooring such as tile.

Table 8 shows the frequency of the dominant types of passive cooling. Most (78%) sites were cooled primarily by direct convection such as windows or vents; 11% used shading of the aperture. Figure 3 shows the schematics for the various cooling system types indicated in Table 8. The distribution of system types differed little between the South and all other regions.

Auxiliary Heating and Cooling

Of the sites audited, 97% use some form of auxiliary heating. A striking finding is the strong preference for wood as an auxiliary heating fuel. Most homeowners burn wood in stoves or fireplaces; a few use wood furnaces. Table 9 presents the data on types of auxiliary heating equipment.

Nearly half of the sites have some form of auxiliary cooling (Table 10). Nearly half of the sites with auxiliary cooling are in the South (Table 11). These tables are most meaningful when aggregated by fuel type and compared with similar data for nonsolar houses. Data for nonsolar homes are taken from the Residential Energy Consumption Survey conducted by the Energy Information Administration of DOE (DOE 1981). Compared with RECS homes, a higher percentage of passive solar houses use electricity as a source of heat. To speculate, this situation probably reflects the flexibility of electric heat for zoning and intermittent use, features that are attractive in a solar house. In a conventional home, the lower first cost of electricity is usually offset by high operational costs, resulting in a high life-cycle cost. In contrast, electric heat can often have a relatively attractive life-cycle cost for a solar house because of relatively low energy consumption for auxiliary heating.

Table 6. Dominant Passive Solar Heating System Types

System Type	Homes %	Homes N
Direct gain (e.g., south-facing windows)	76	(240)
Storage wall (e.g., Trombe wall)	10	(33)
Isolated storage wall or floor, (e.g., storage insulated from living space)	8	(25)
Collection wall (e.g., thermosiphoning hot air collector)	3	(10)
Shaded direct gain roof (e.g., clerestory)	2	(7)
Storage roof (e.g., roof pond)	1	(1)
Direct gain roof (e.g., skylights)	1	(1)
Other	1	(1)
Totals	100	(318)
Missing data		(3)
Total N		(321)

Data from audit, item 30.

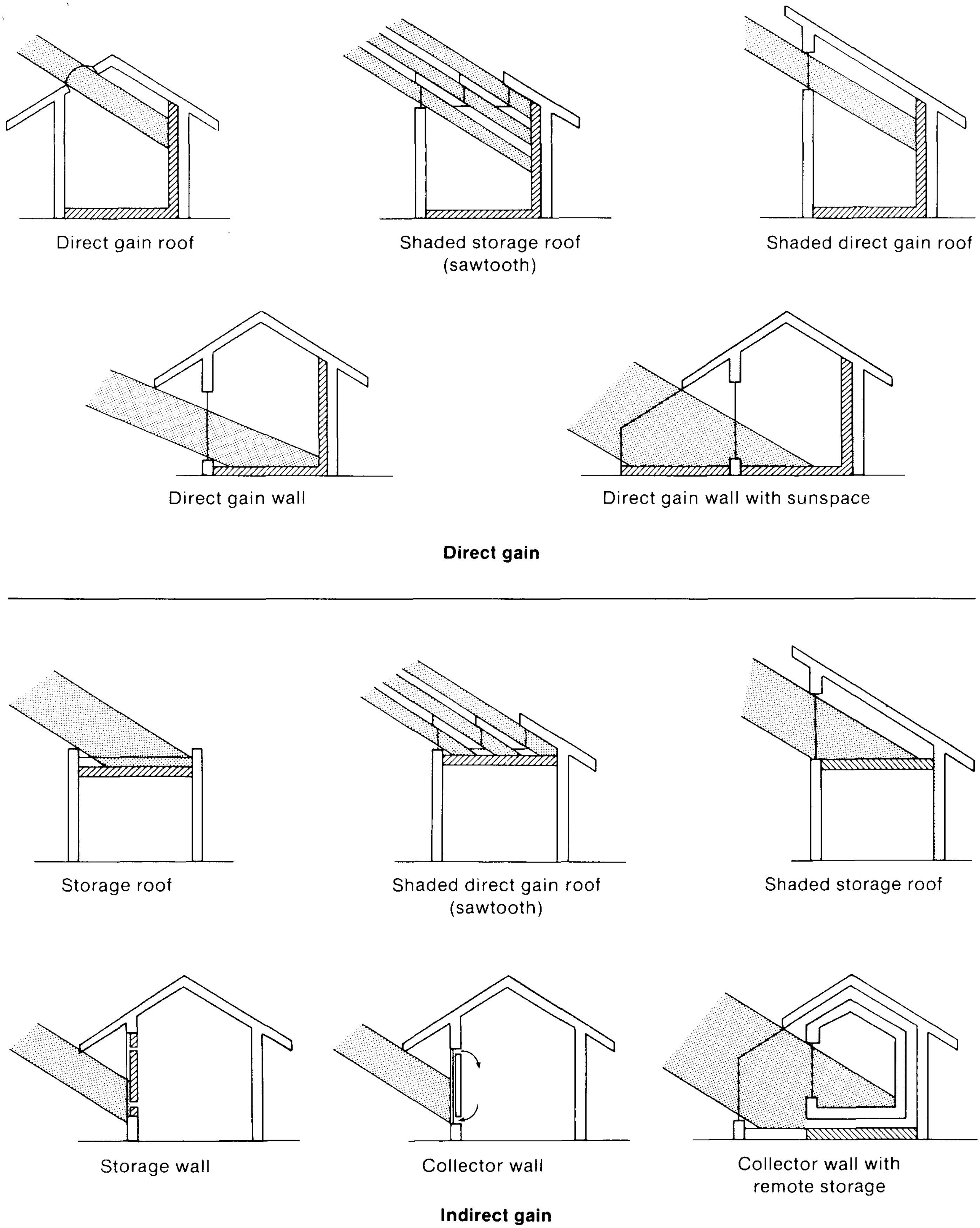

Figure 2. Schematics of passive heating system types

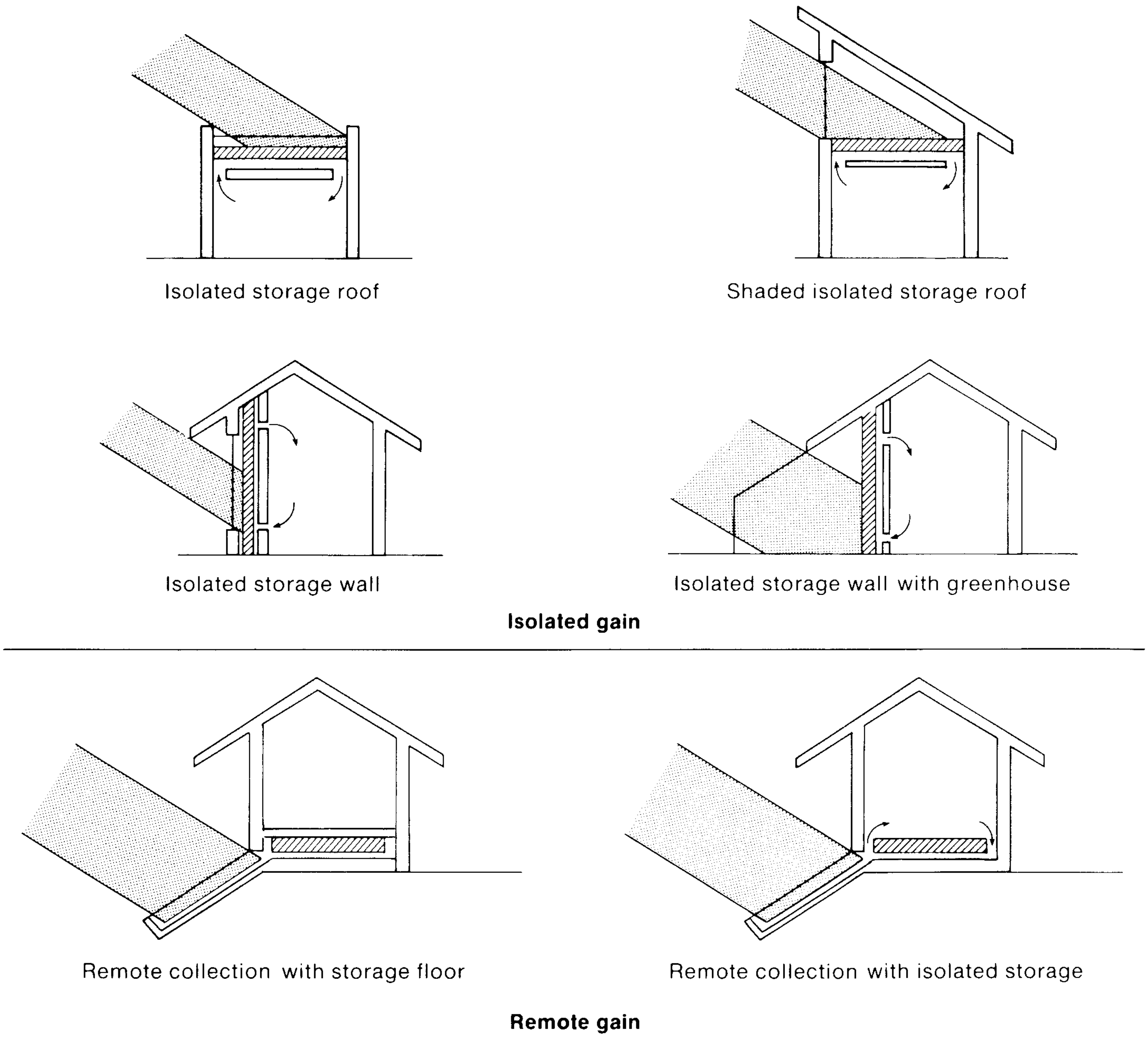

Figure 2. Schematics of passive heating system types (concluded)

Table 7. Primary Mass Configuration

Mass Configuration	Type[a]	Homes %	N
Directly sunlit floor of living space (e.g., floor slab)	D	32	(75)
Directly sunlit wall of living space (e.g., brick wall sunlit through clerestory)	B	17	(39)
Mass located remote from living space (e.g., rock bin)	G	13	(31)
Wall of living space sunlit on outside surface (e.g., Trombe wall)	A	13	(29)
Mass in sunspace with controlled air flow into living space (e.g., greenhouse with vents into house)	C	11	(25)
Floor, walls, or ceiling of living space which receives only reflected solar radiation (e.g., brick chimney never directly sunlit)	E	9	(21)
Floor, walls, or ceiling of living space which does not receive direct or reflected solar radiation (e.g., masonry walls in north rooms)	F	5	(12)
Totals		100	(232)
Missing data			(89)
Total N			(321)

Data from occupant questionnaire, item 43.

[a]For description of type, see Chart H in Appendix D.

Table 8. Dominant Passive Cooling System Types

System Type[a]	South %	South N	National %	National N
Direct convection cooling	59	(40)	79	(180)
Shading	24	(16)	11	(26)
Direct ground cooling	6	(4)	3	(7)
Isolated ground cooling	4	(3)	2	(5)
Indirect ground cooling	3	(2)	2	(4)
Indirect convection cooling	3	(2)	1	(3)
Radiative cooling	1	(1)	1	(2)
Isolated convection cooling	0	(0)	1	(1)
Totals	100	(68)	100	(228)
Missing data[b]		(18)		(93)
Total N		(86)		(321)

Data from audit, item 30.

[a]See Figure 3 and Appendix D for definitions and illustrations of system types.

[b]Includes those without cooling.

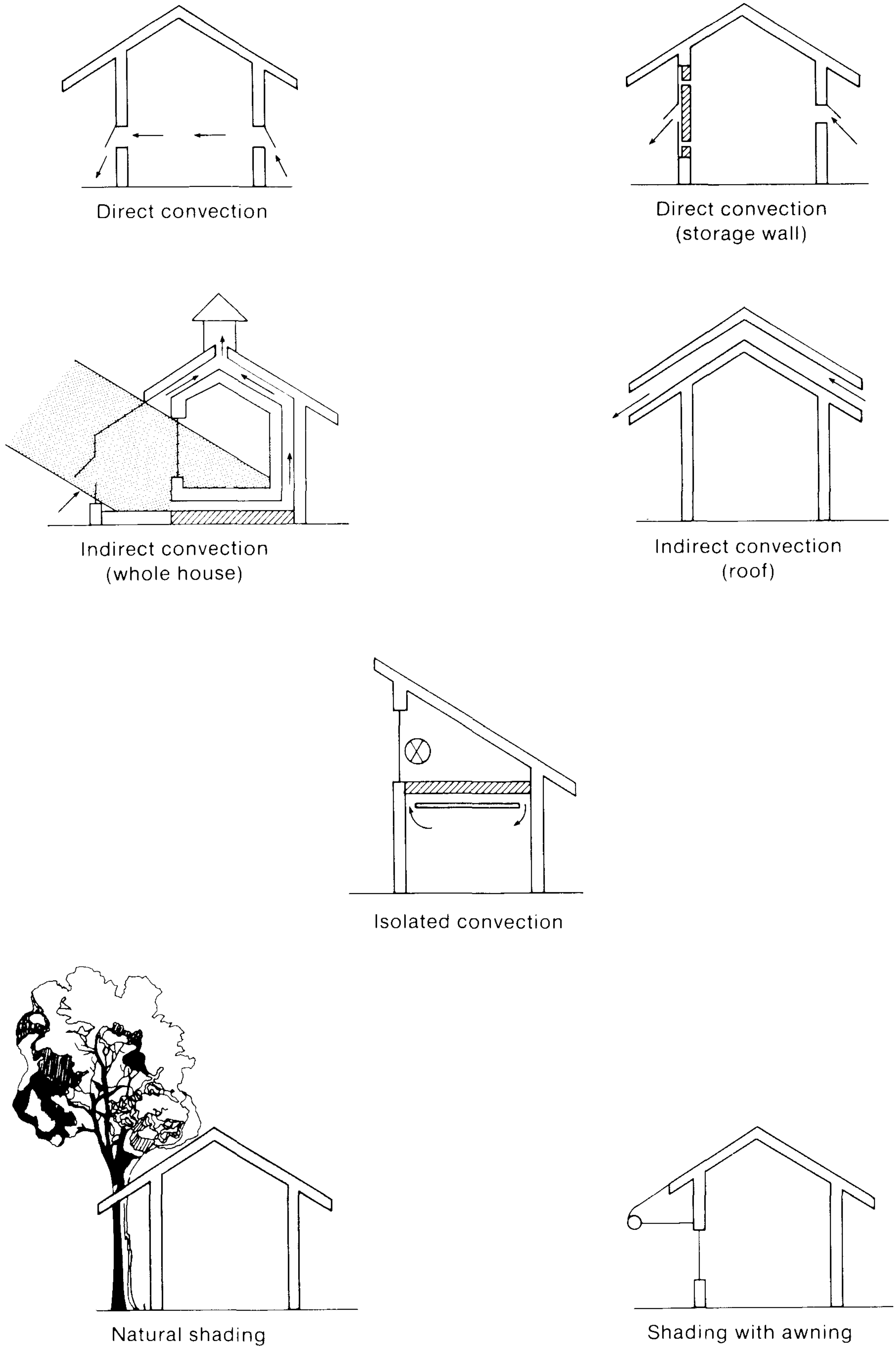

Figure 3. Schematics of passive cooling system types

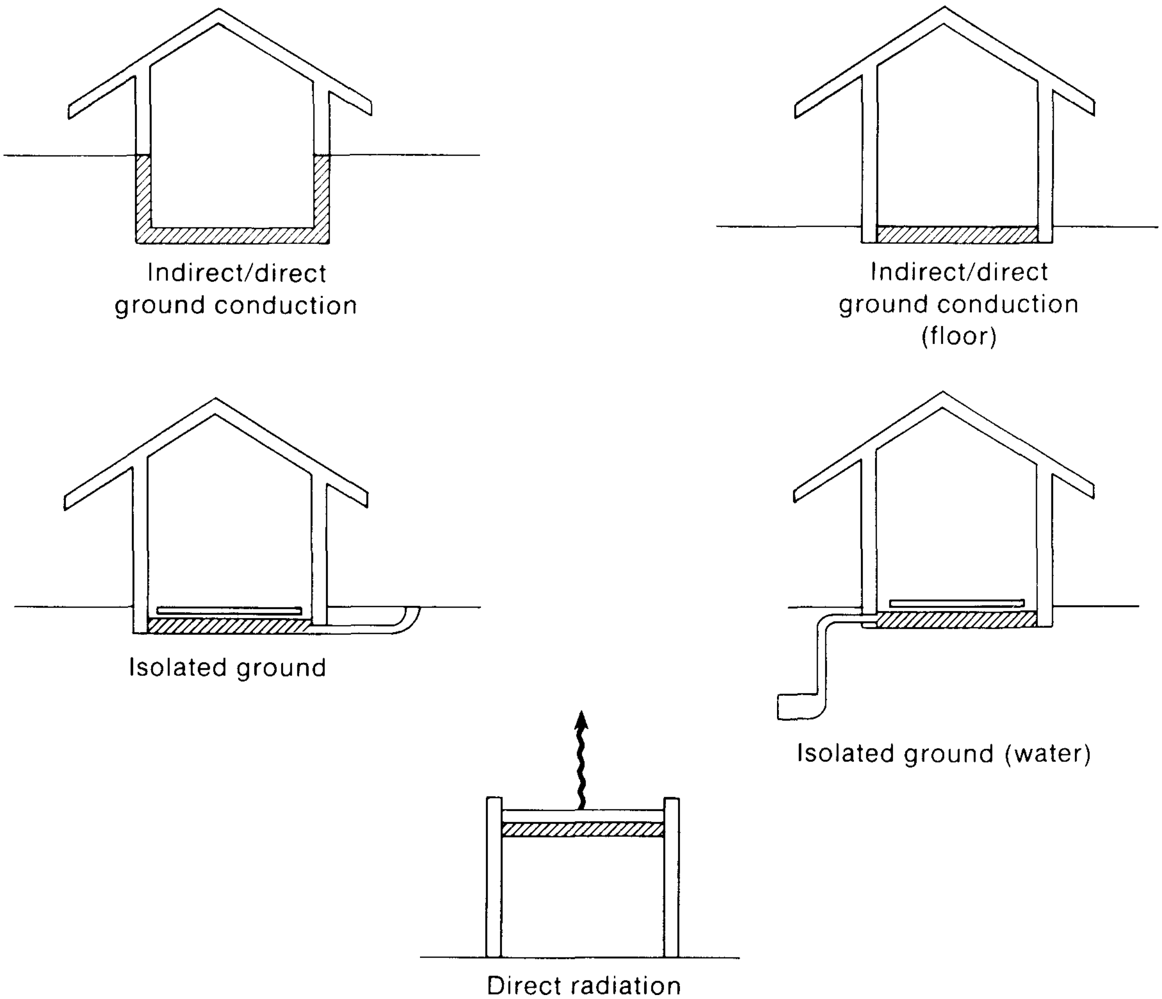

Figure 3. Schematics of passive cooling system types (concluded)

Table 9. Types of Auxiliary Heating Equipment

Type of Equipment	Homes %	Homes N
Oil-fired hot air furnace	4	(14)
Oil-fired hydronic space heat	1	(3)
Oil-fired hydronic space and water heat	2	(7)
Gas-fired central hot air furnace	18	(56)
Gas-fired space heater	1	(2)
Gas-fired hydronic space heater	3	(9)
Electric hot air furnace	3	(10)
Electric resistance heating	6	(18)
Electric radiant heating	2	(5)
Heat pump	14	(43)
Wood-fired hot air furnace	2	(7)
Wood-fired hydronic space and water heat	1	(2)
Woodstove or fireplace	42	(132)
Woodstove and water heat combination	1	(4)
Totals	100	(312)
Missing data		(9)
Total N		(321)

Data from audit, item 26.

Table 10. Auxiliary Cooling Equipment Types

Auxiliary Cooling Type	South %	South N	National %	National N
Air conditioner	42	(29)	32	(45)
Heat pump	29	(20)	28	(40)
Ventilation fan	19	(13)	27	(39)
Attic vent fan	10	(7)	10	(14)
Evaporative cooler	0	(0)	2	(3)
Dehumidifer	0	(0)	1	(2)
Totals	100	(69)	100	(143)
Missing data				(178)
Total N				(321)

Data from audit, item 26.

Table 11. Auxiliary Cooling Systems by Region

Auxiliary Cooling	Sites %	Sites N
South	48	(69)
Mid America	22	(31)
Northeast	21	(30)
West	9	(13)
Totals	100	(143)
Missing data		(178)
Total N		(321)

Data from audit, item 26.

Figures 4 through 7 present the data on fuel type for each region with similar data for nonsolar homes. The differences from region to region reflect the availability of different fuels; for example, oil is more available in the Northeast and gas in the Midwest. The respondents' preference for wood over oil and gas is most marked in the Northeast and the West. In the South and Mid-America, while wood is not the predominant fuel for auxiliary heat, it is still used more in the solar homes presented in the study than in nonsolar homes. In the South, electricity is the most popular source of auxiliary heat; in Mid-America, gas is. In all regions, electricity is used in a higher percentage of the solar homes than in the detached nonsolar homes presented in the studies.

Figure 8 shows a national summary of these data, including a comparison with data on the energy sources of the primary heating systems installed by NAHB builders in 63,754 detached dwellings completed in 1979 (NAHB Research Foundation 1981). These data are presented for overall comparison, and no attempt has been made to examine the comparability of the buildings in each study. The homes in the NAHB study show an increased reliance on electric heat and no use of wood as a primary heat source. Part of this difference could be a result of the data collection: the NAHB study sampled builders' expectations of energy use in the homes, and the other two studies questioned the residents themselves.

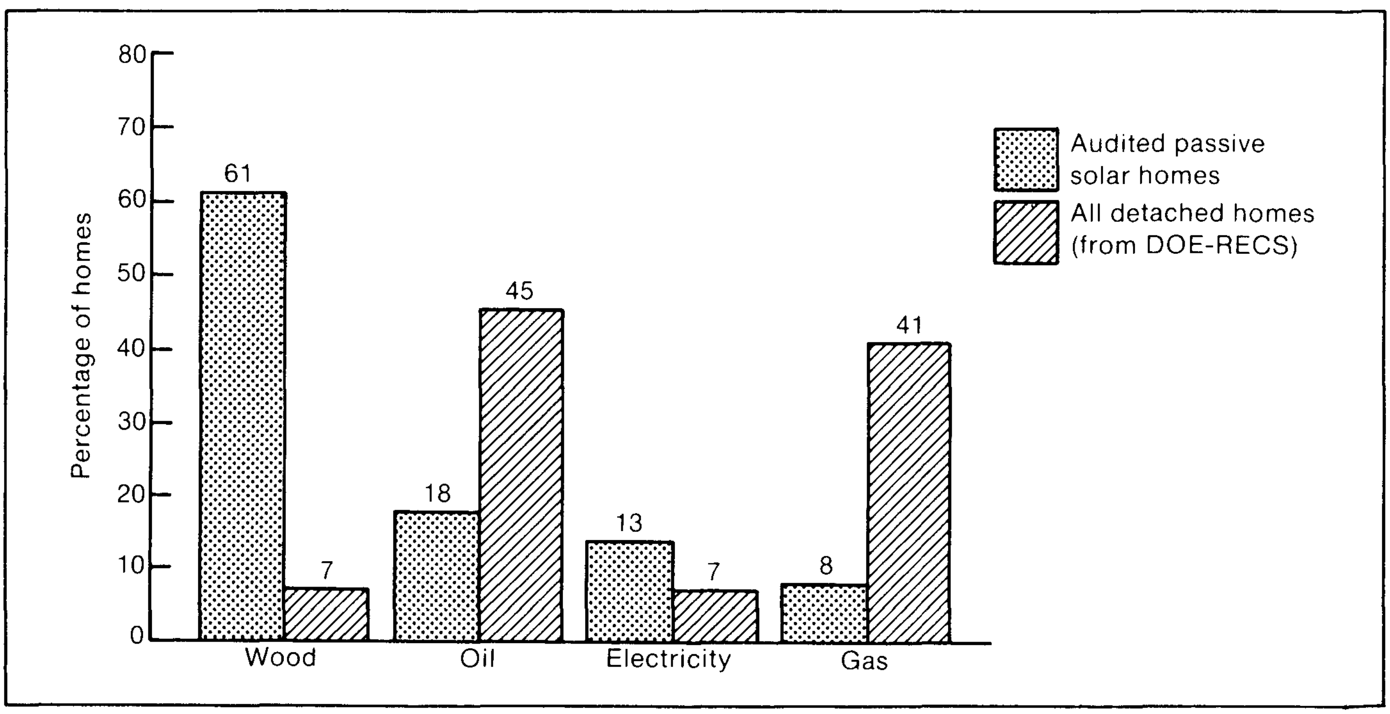

Figure 4. Comparison of nonsolar heating energy sources — Northeast

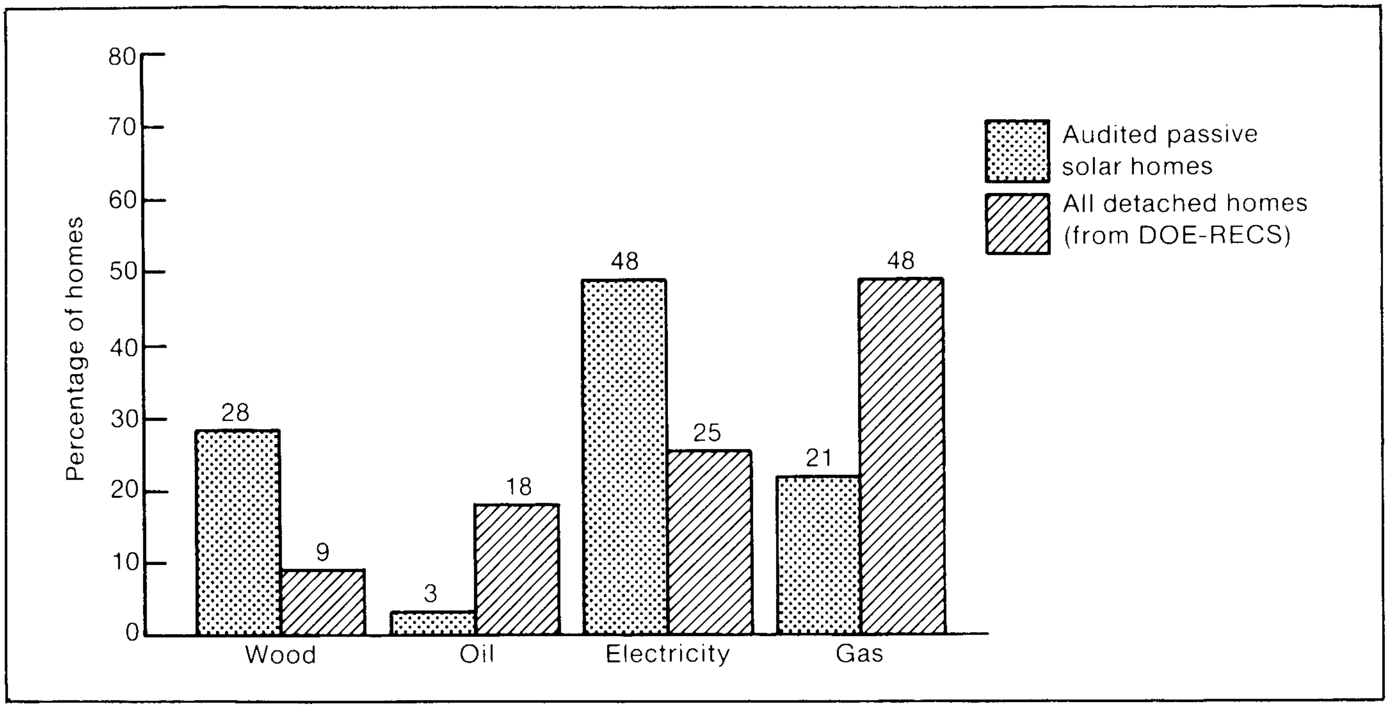

Figure 5. Comparison of nonsolar heating energy sources — Southeast

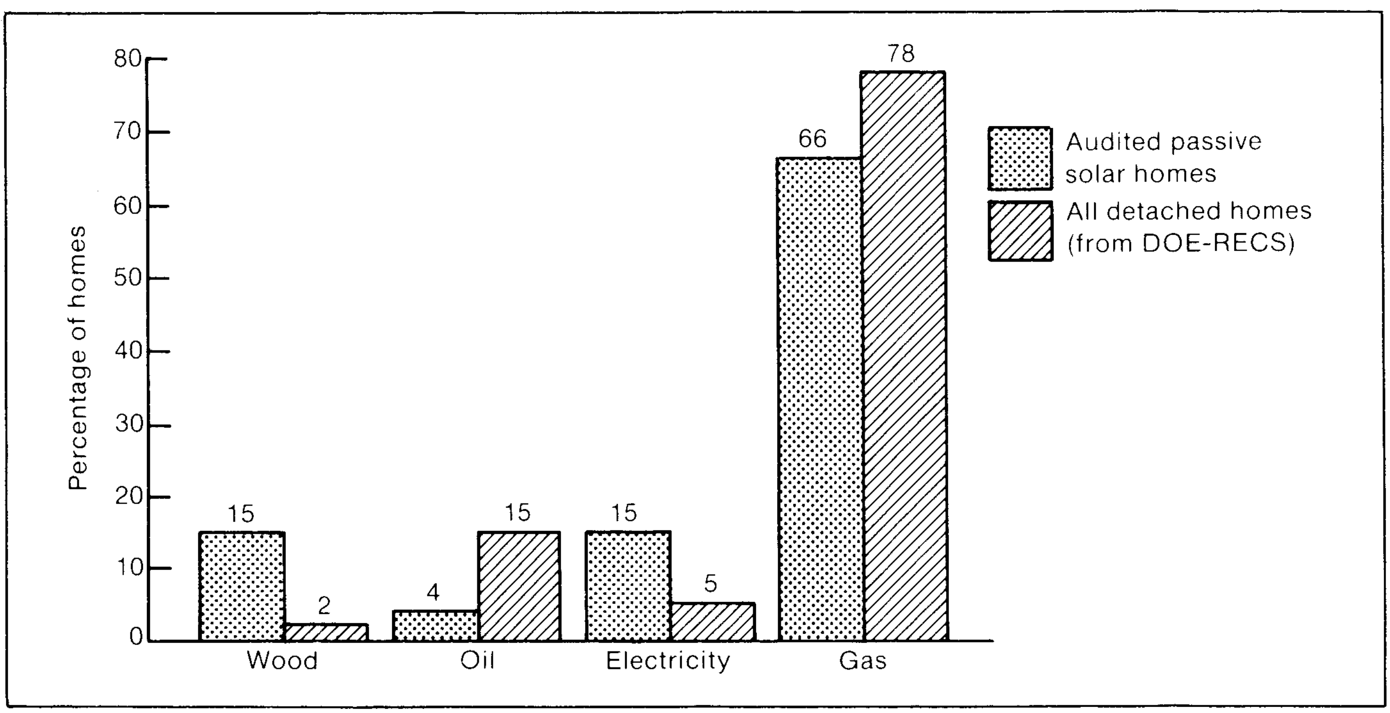

Figure 6. Comparison of nonsolar heating energy sources — Mid-America

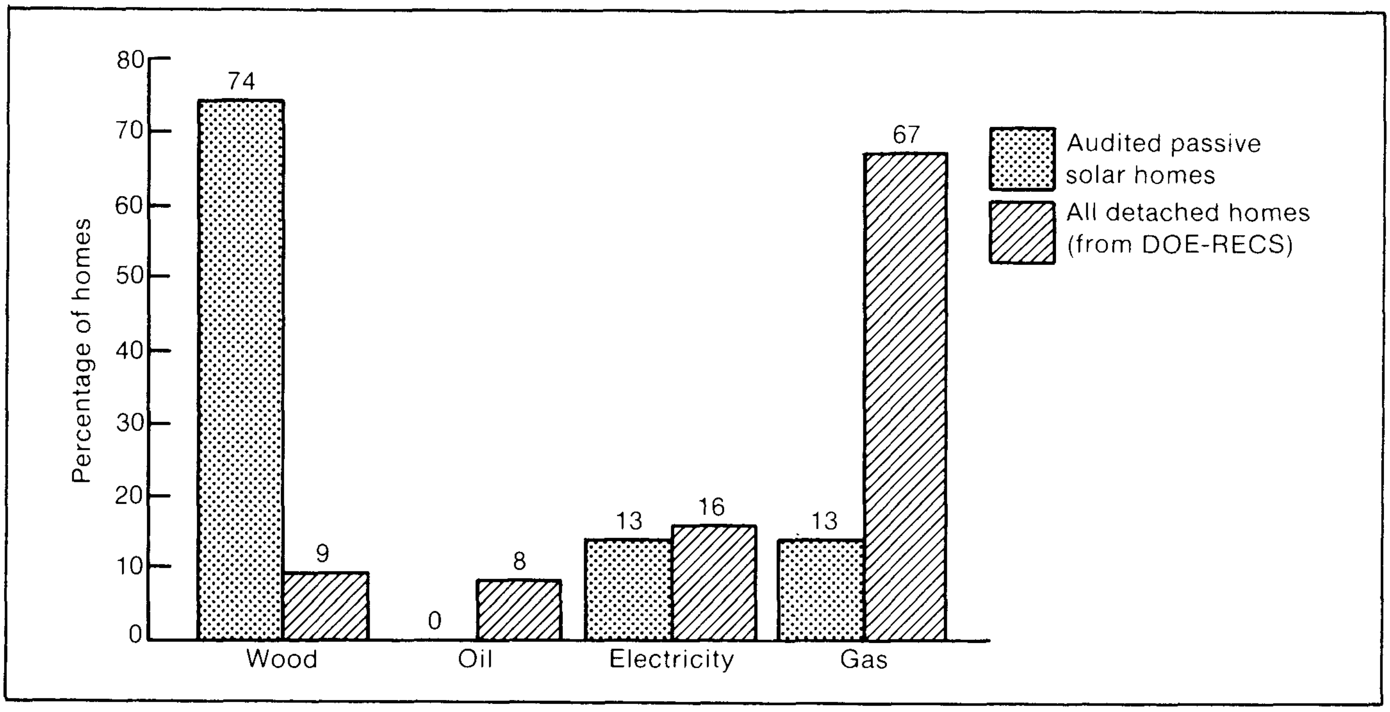

Figure 7. Comparison of nonsolar heating energy sources — West

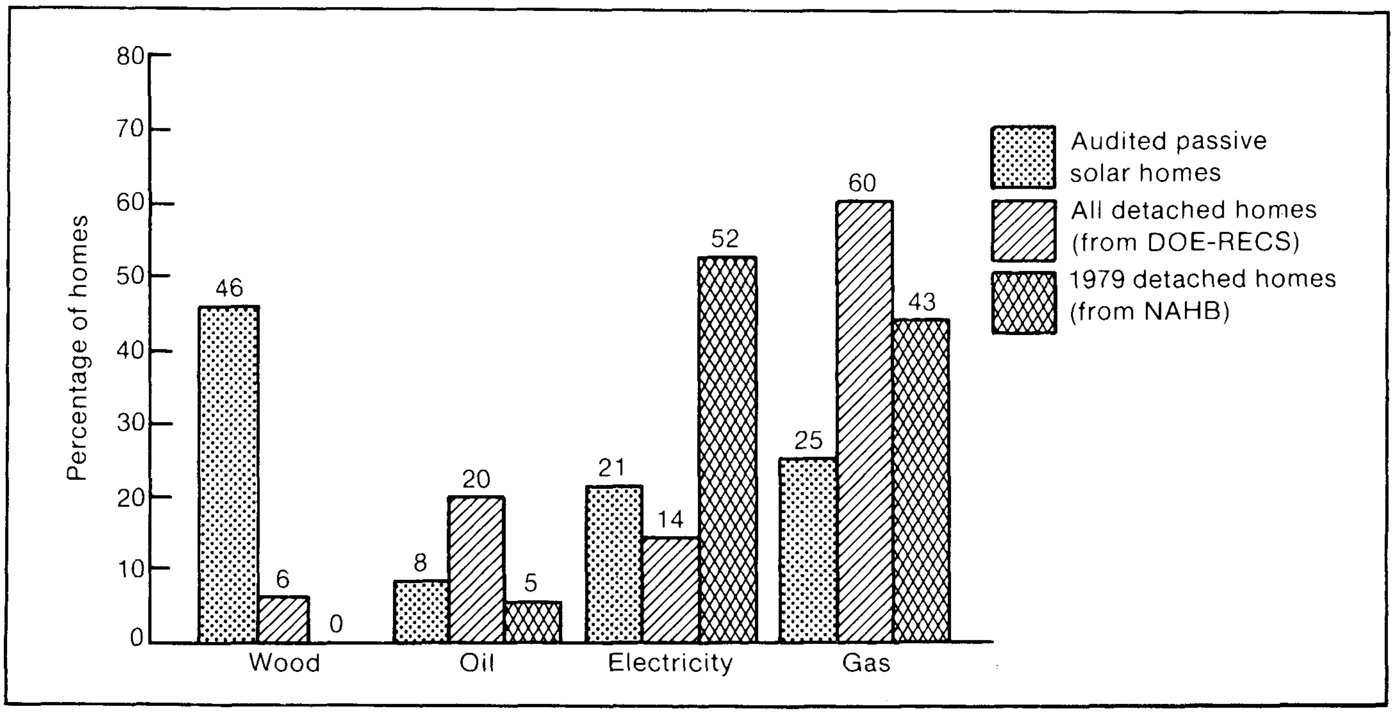

Figure 8. Comparison of nonsolar heating energy sources — National

Selected Energy Use Factors

Indoor Temperature

Unlike conventionally heated houses, many sites did not have thermostats, often because wood stoves were the primary heating source. In many cases, therefore, the indoor temperatures reported on the audit form were based on the occupants' perception of the temperature, sometimes verified with a thermometer. The average indoor temperature for all sites was 65.5°F (18.6°C), average daytime temperature was 68.1°F (20.1°C), and average nighttime temperature was 63.1°F (17.3°C). More than 75% of the sites maintained an average daytime temperature of between 64°F (17.8°C) and 72°F (22.2°C). Figures 9 and 10 summarize these data and invite closer scrutiny and comparison with similar data for nonsolar homes. Occupants of cooler houses often had some explanation such as the house was unoccupied during the day or for part of the winter. In spite of the enormous climatic differences between sites, average indoor temperatures did not differ appreciably among regions.

For occupants of a passive solar home, the swings in temperature experienced on sunny days in the spring and fall can be uncomfortable. These temperature differences can be buffered by movable insulation and auxiliary heating and cooling. Table 12 shows the data for daytime minus nighttime temperature. No appreciable difference between daytime and nighttime temperatures was recorded in 17% of the sites. Almost half (46%) showed a 5°F (3°C) or less difference and 89% had a difference of 10°F (5°C) or less, leaving 11% with more than a 10°F (5°C)

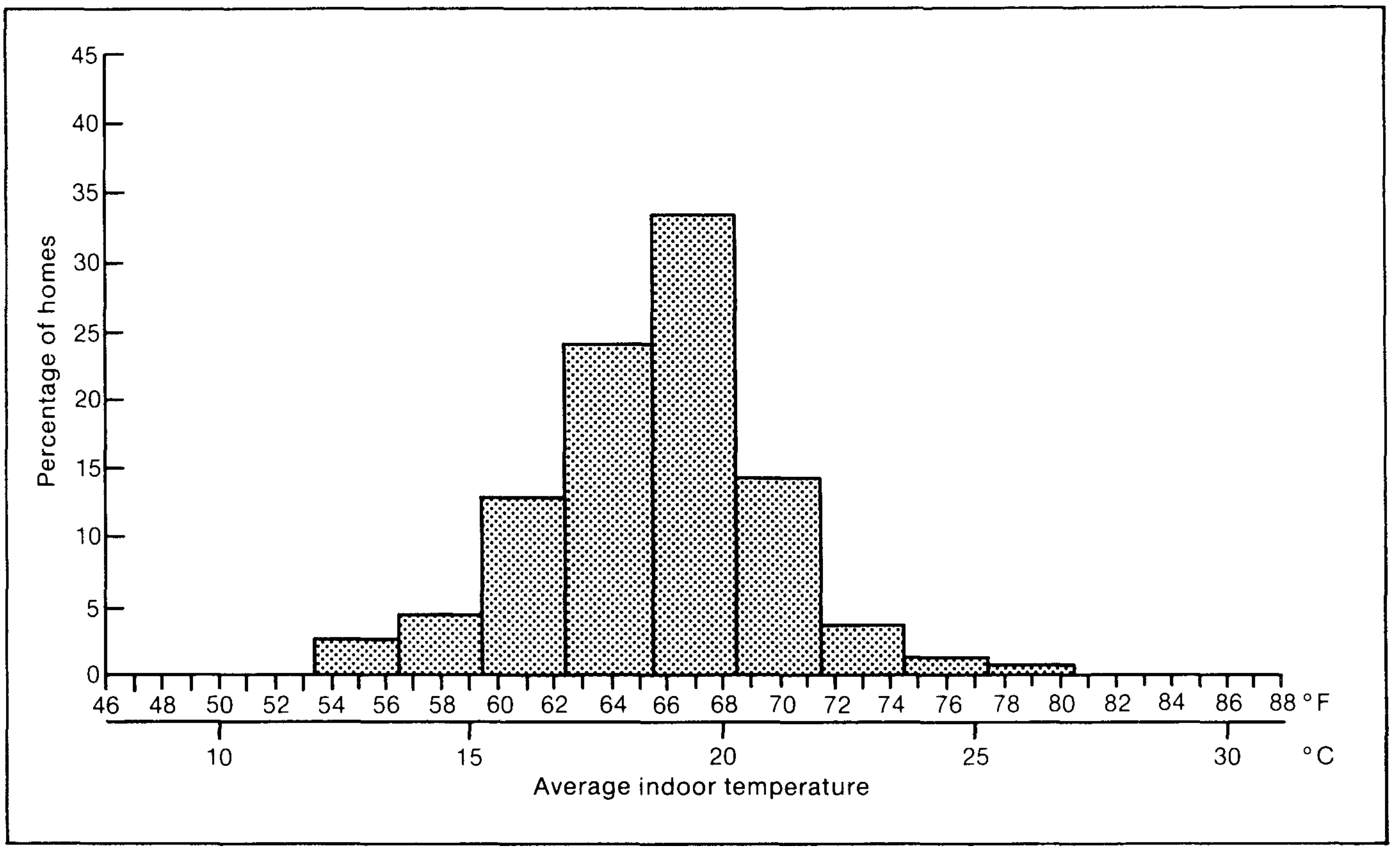

Figure 9. Average indoor temperature

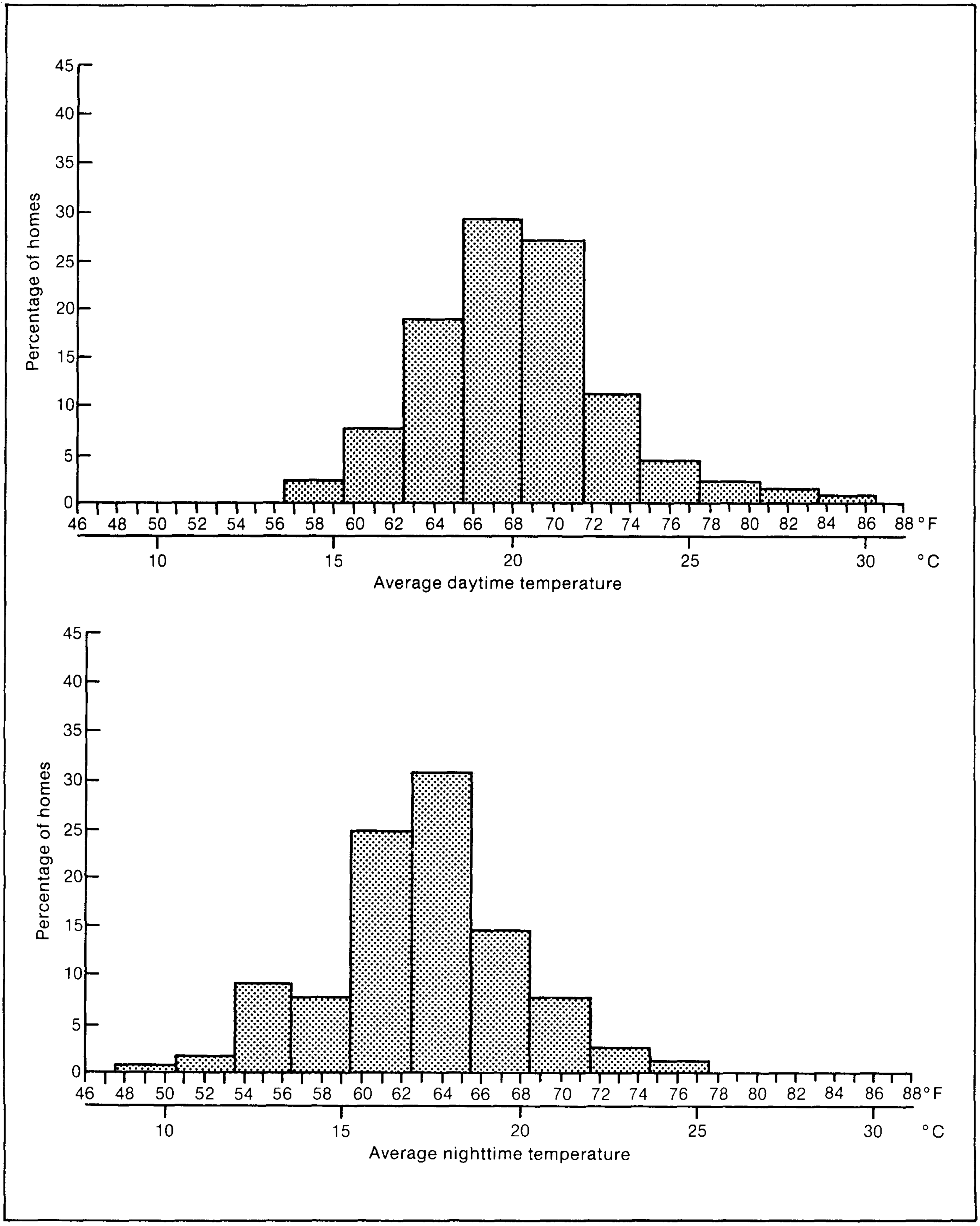

Figure 10. Average day- and nighttime temperatures

Table 12. Difference Between Day- and Nighttime Indoor Temperatures

Temperature Difference, °F (°C)	Sites %	N
0	17	(51)
1-5 (0.5-2.8)	39	(117)
6-10 (3.3-5.5)	33	(100)
11-20 (6.1-11.1)	11	(32)
Totals	100	(300)
Missing data		(21)
Total N		(321)

Data from audit, item 22.

difference. These differences are probably greater than those experienced in nonsolar houses and reflect the effects of the solar design as well as night setback strategies. At eight sites the mean nighttime temperature exceeded the mean daytime temperature, probably because those homeowners used a daytime setback or did not burn wood during the day when they were *not* home.

Hot Water Use

The mean hot water use per person per day for all the sites was 21.4 gal (81 l) (see audit, item 27). Because the mean number of occupants in the audited homes was three, this figure is comparable to the national average of hot water use estimated at 64.3 gal (244 l) per household per day. About a fifth of the sites had solar-heated domestic hot water.

Selected Energy Use Indicators

Building Heat Loss

Heat loss can be considered to be a measure of the level of insulation and the tightness of the house. The three aspects of estimated heat loss are presented: estimated total net heat loss (Figure 11); infiltration rates (Figure 12); and estimated normalized loss factor (Figure 13), which is the net heat loss factor per house divided by the square footage. All values have been estimated by the auditors based on their inspection of the homes. Heat loss and infiltration are estimated using standard techniques applied to all homes.* The mean normalized loss factor (NLF)

*These techniques were developed from standard ASHRAE practices and the DOE Model Audit for the Residential Conservation Service. Details of the assumptions made and calculation techniques can be found in the audit form (Appendix B), the Instructions to Auditors (Appendix C), and the Reference Charts (Appendix D).

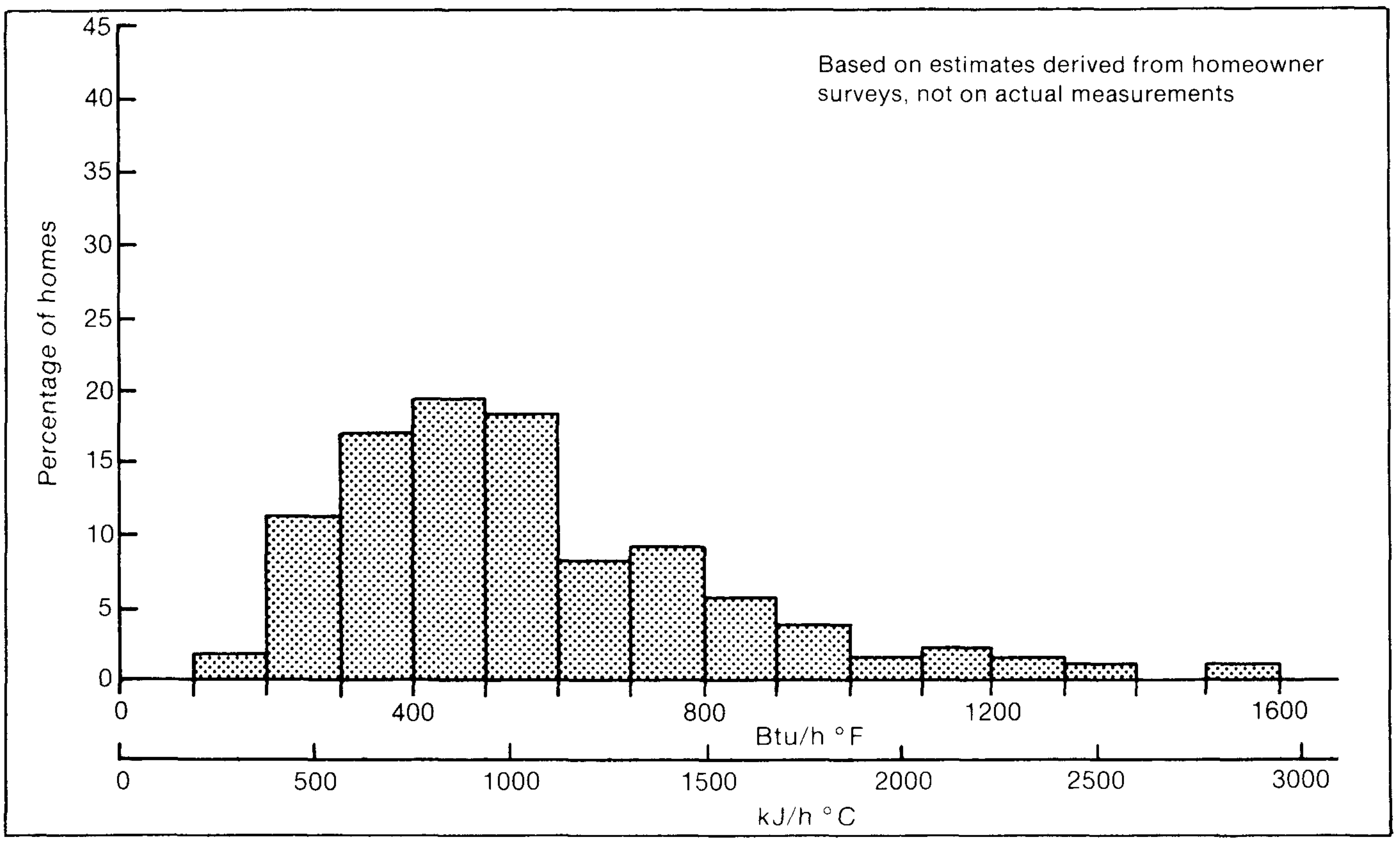

Figure 11. Total net heat loss

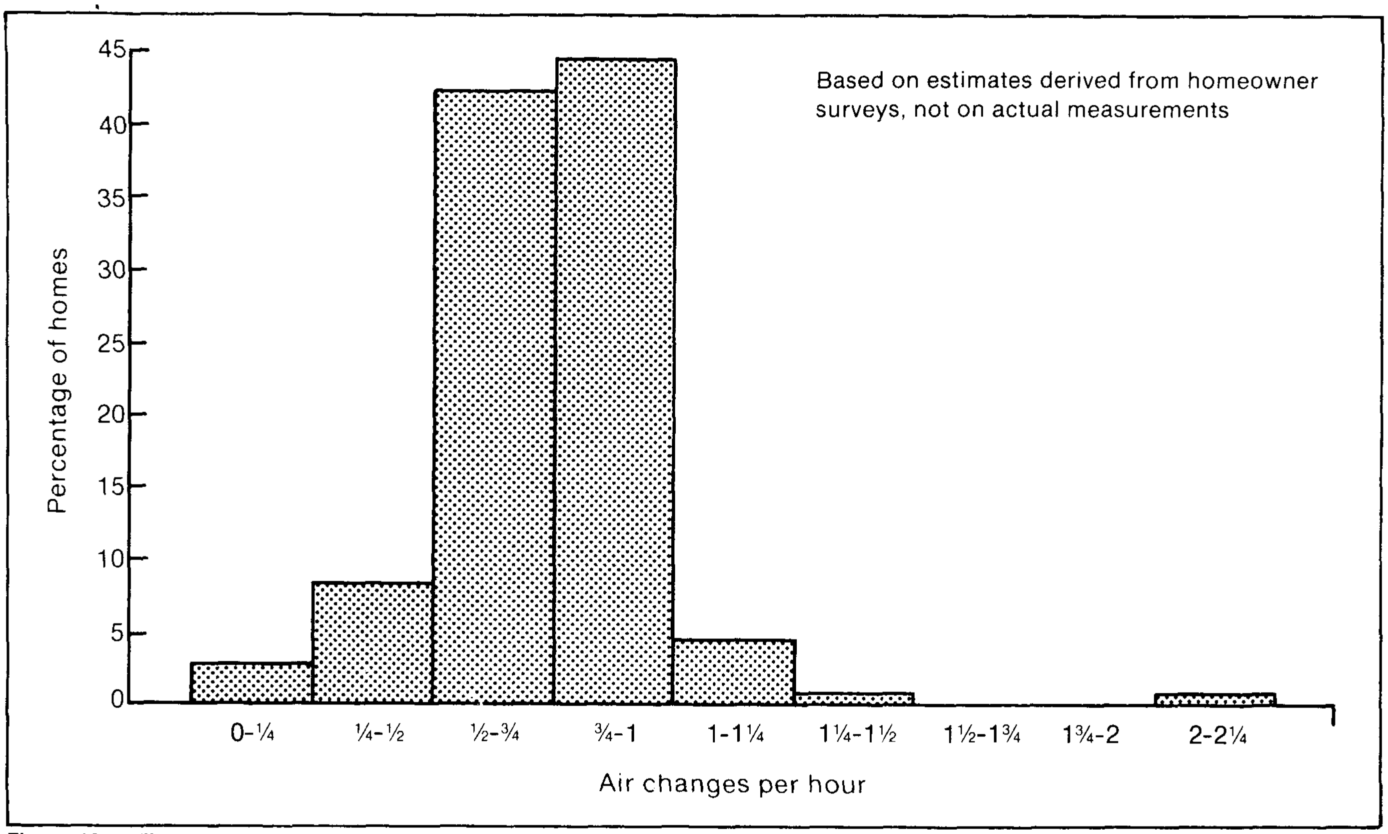

Figure 12. Infiltration rate

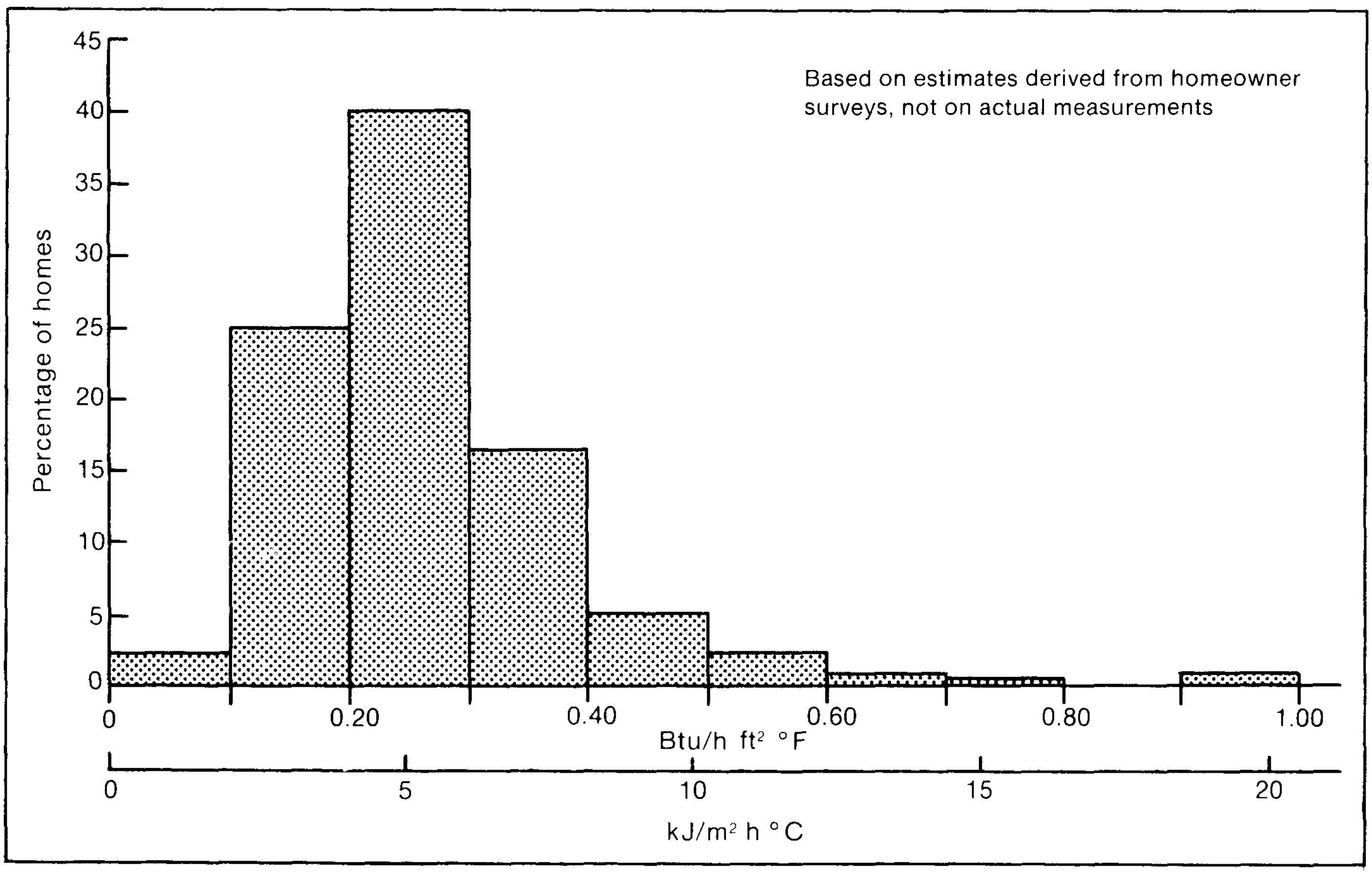

Figure 13. Normalized loss factor (321 sites)

for all audited sites is 0.26 Btu/ft^2 h °F (5.31 kJ/m^2 h °C). Draftier homes — those with a higher estimated infiltration rate — have a mean NLF of 0.31 Btu/ft^2 h °F (6.33 kJ/m^2 h °C). The total household heat loss in colder areas is about the same as in warmer areas.

Total Purchased Energy

Total purchased energy (TPE) is the annual sum of the energy contents of all purchased fuels, expressed in British thermal units (Btu). Information on oil, gas, and electricity was gathered from occupant records, utilities, and fuel suppliers. The data include all nonsolar energy consumption with the exception of wood, which was estimated by the occupants. Sites were eliminated if the occupants could not confidently estimate their wood use to a quarter of a cord.

Because TPE is a measure of energy supplied, buildings that use mostly electricity, for instance, will tend to have lower TPEs than those that use substantial amounts of oil, gas, or wood. In buildings using these fuels, only a fraction of their energy value is delivered to the load because of conversion inefficiencies. Typical gas furnaces, for example, can have a system efficiency as low as 50%. Newer, high efficiency units can approach 90% to 95%. Accordingly, TPE should be seen not as an index of energy demand for heating and cooling, but rather as an index of household demand on available energy resources.

Figures 14 through 18 present histograms of total purchased energy for each region and all sites nationally. The data show a wide range of TPE usages in all climates, demonstrating the variability of the homes' construction and design features. Values at the low end of the scale indicate that certain building techniques are successful in any climate. Table 13 shows the mean TPE for all audited homes and a regional comparison. In addition, the table provides a comparison to national statistics on residential energy use. Although the buildings in the two samples differ (age, type of construction, etc.) the savings achieved in the passive homes are substantial. Compared with overall averages for households in the United States, the total purchased energy is lower in all regions except the south. The sites in the Mid-America region were particularly low.

Building Performance Index

Building performance index (BPI) is defined as the total purchased energy (TPE) normalized by dividing it by floor area. Because the floor areas of the passive solar homes in the Class C study are

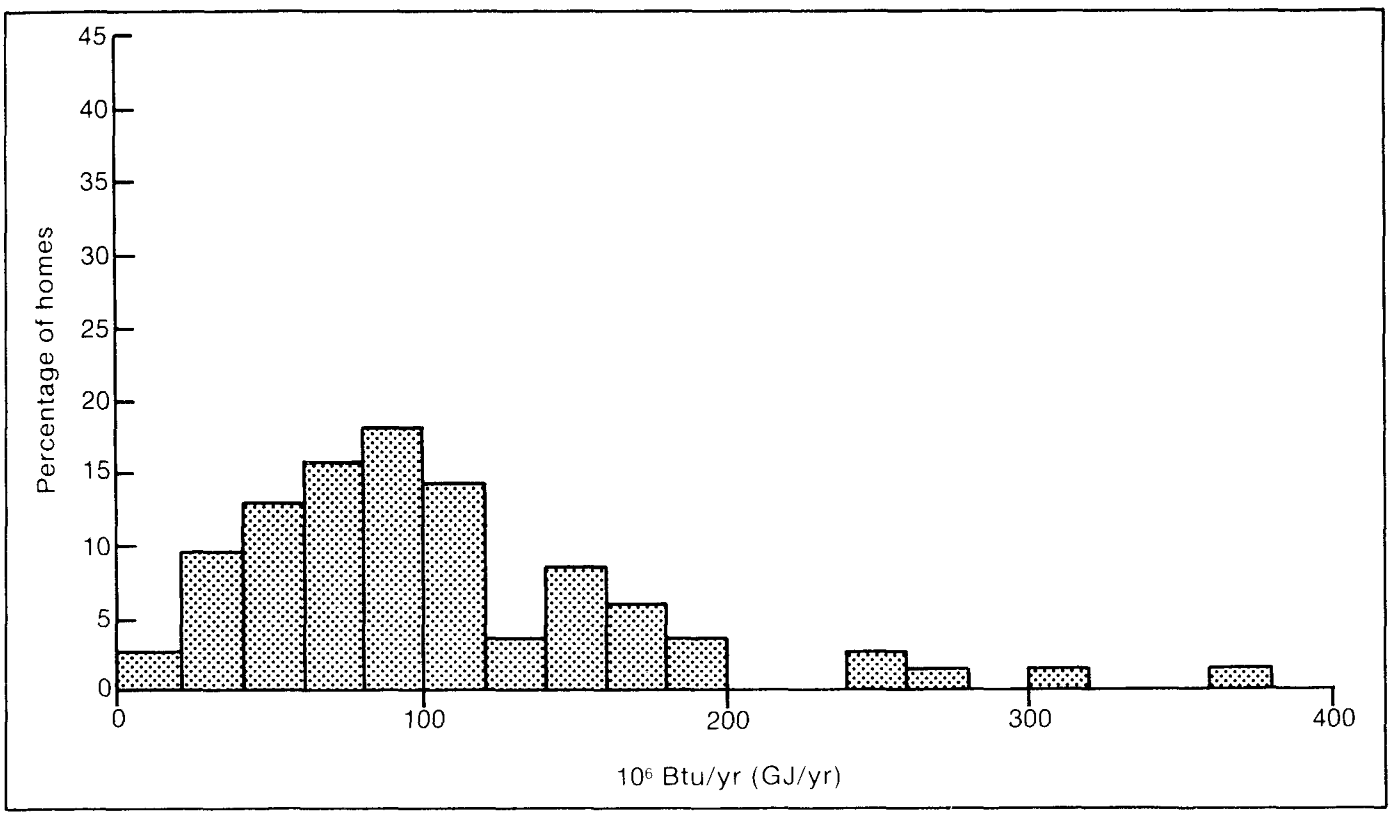

Figure 14. Annual total purchased energy — Northeast (86 sites)

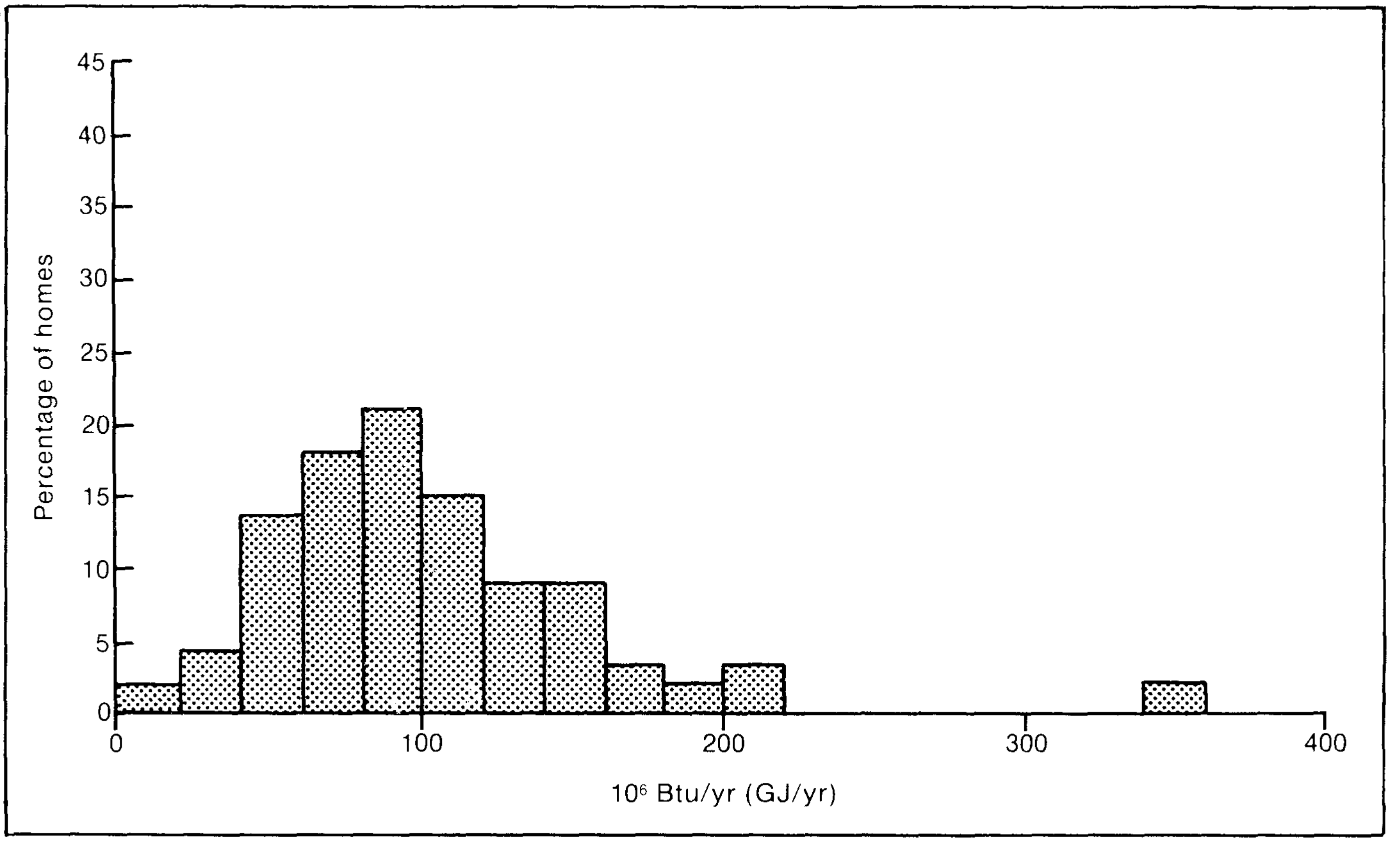

Figure 15. Annual total purchased energy — South (66 sites)

Figure 16. Annual total purchased energy — Mid-America (72 sites)

Figure 17. Annual total purchased energy — West (36 sites)

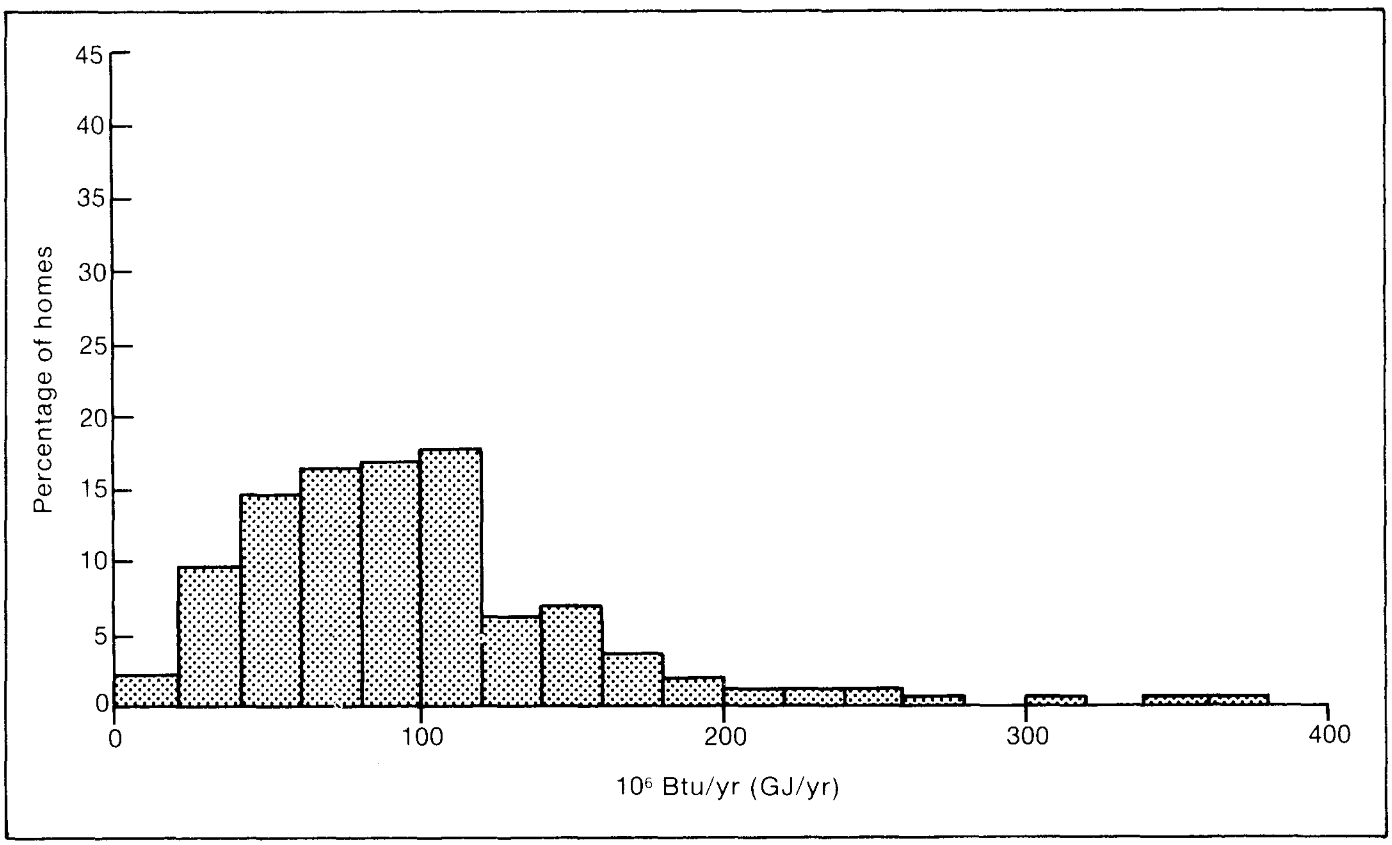

Figure 18. Annual total purchased energy — National (244 sites)

Table 13. Total Purchased Energy

	Class C Study Mean TPE 10^6 Btu (GJ)	RECS Data[a] Mean TPE 10^6 Btu (GJ)
Northeast	100	138
South	100	96
Mid-America	91	139
West	70	86
National	95	114

Data from audit, item 50.

[a]From DOE 1980.

generally larger than those of average homes, this normalization makes the comparison of solar and nonsolar homes more reasonable. This normalized figure also provides an index for comparing passive solar homes of different sizes. Like TPE, the BPI varies among the homes in the study and should be seen as an index of relative impact on regional or national energy supplies. The range of estimates shows the overall effectiveness of the design choices made and gives designers a measure of energy intensity to use during the design phase.

Although this survey was of passive solar homes, about 7% of the homeowners incorporated an active space heating system into their designs. Half of these were air systems, and half were water systems. The overall BPI did not differ among sites with and without active systems.

Figures 19 through 22 are histograms of BPI for sites in each region. Figure 23 is a histogram of BPI for all

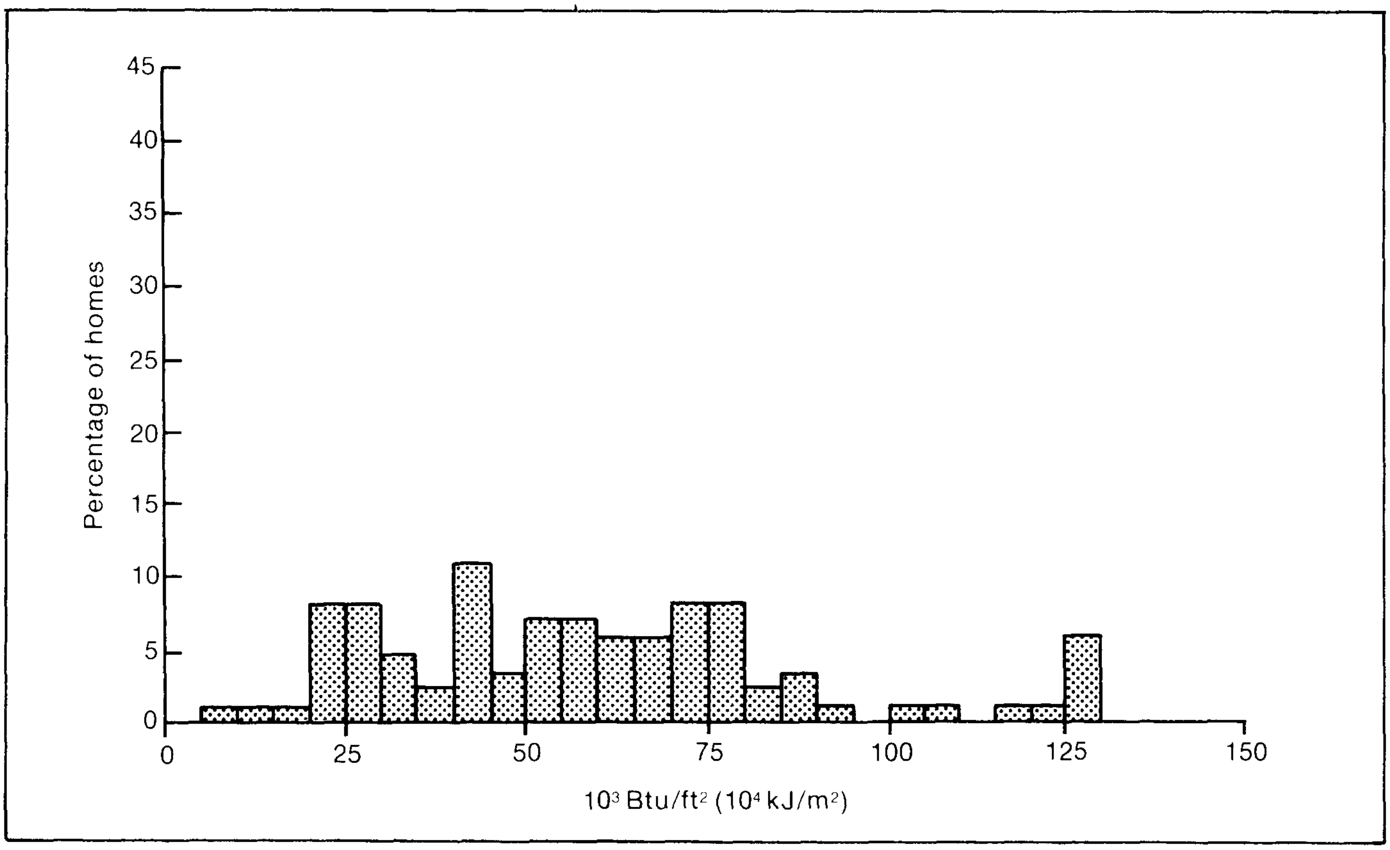

Figure 19. Annual building performance index — Northeast (86 sites)

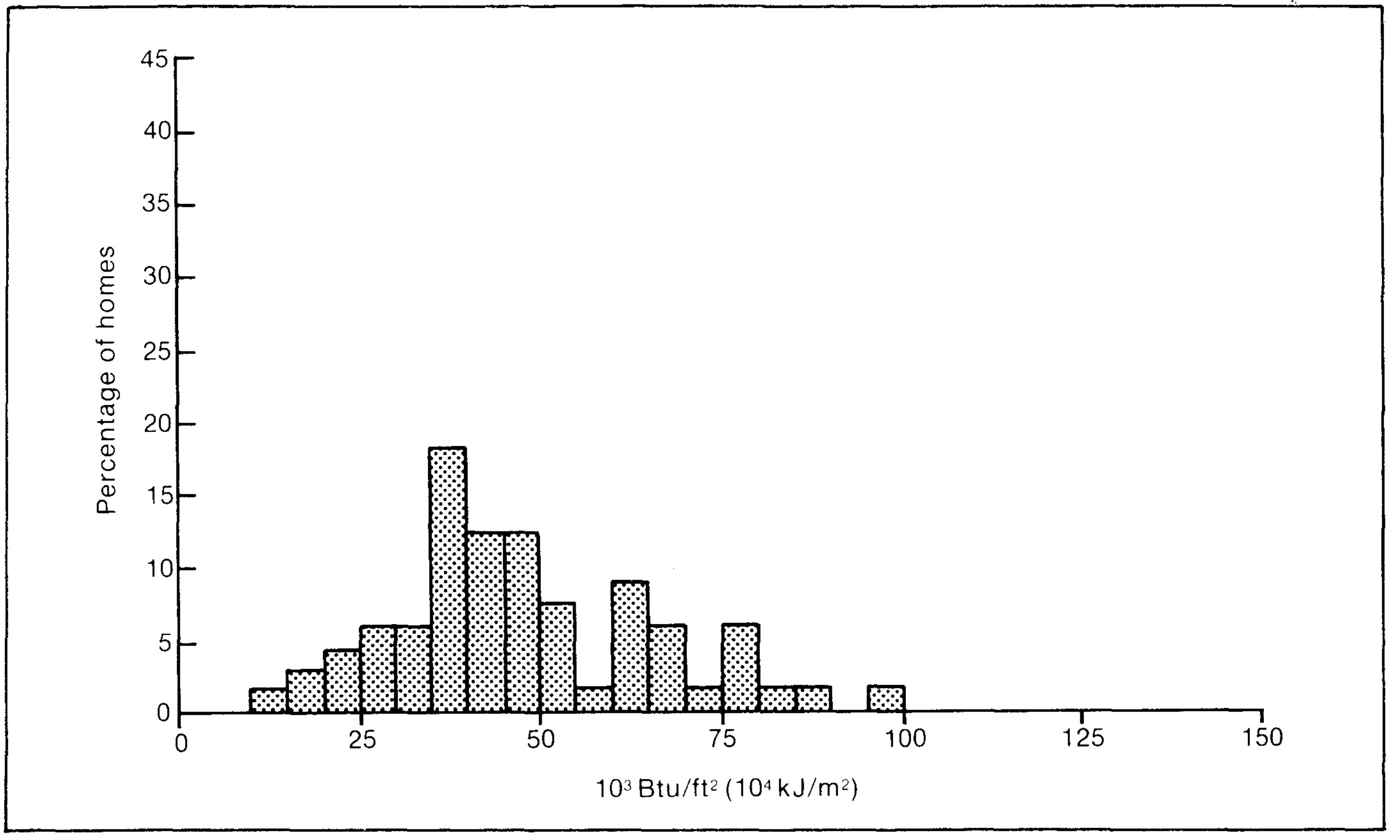

Figure 20. Annual building performance index — South (66 sites)

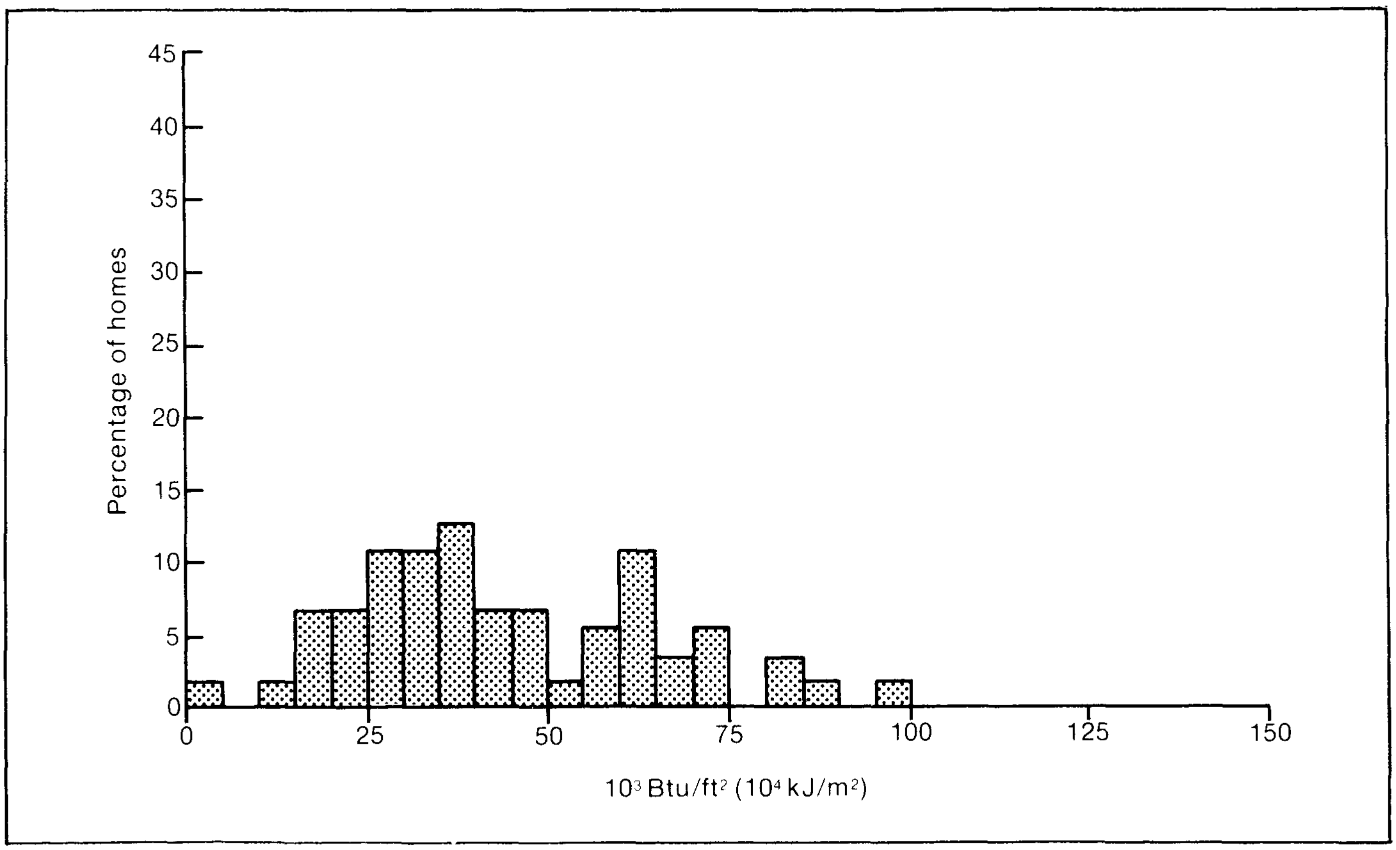

Figure 21. Annual building performance index — Mid-America (72 sites)

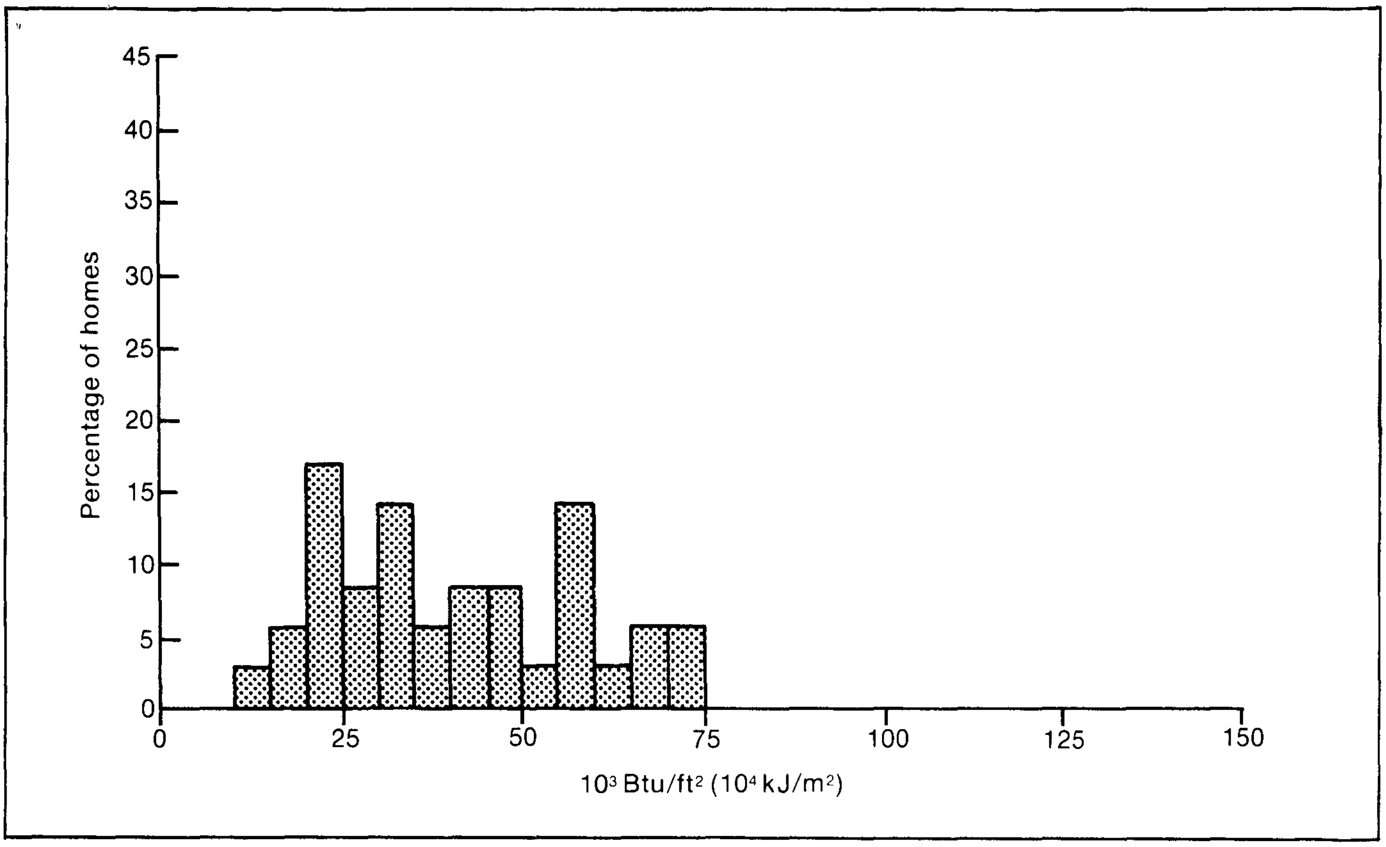

Figure 22. Annual building performance index — West (36 sites)

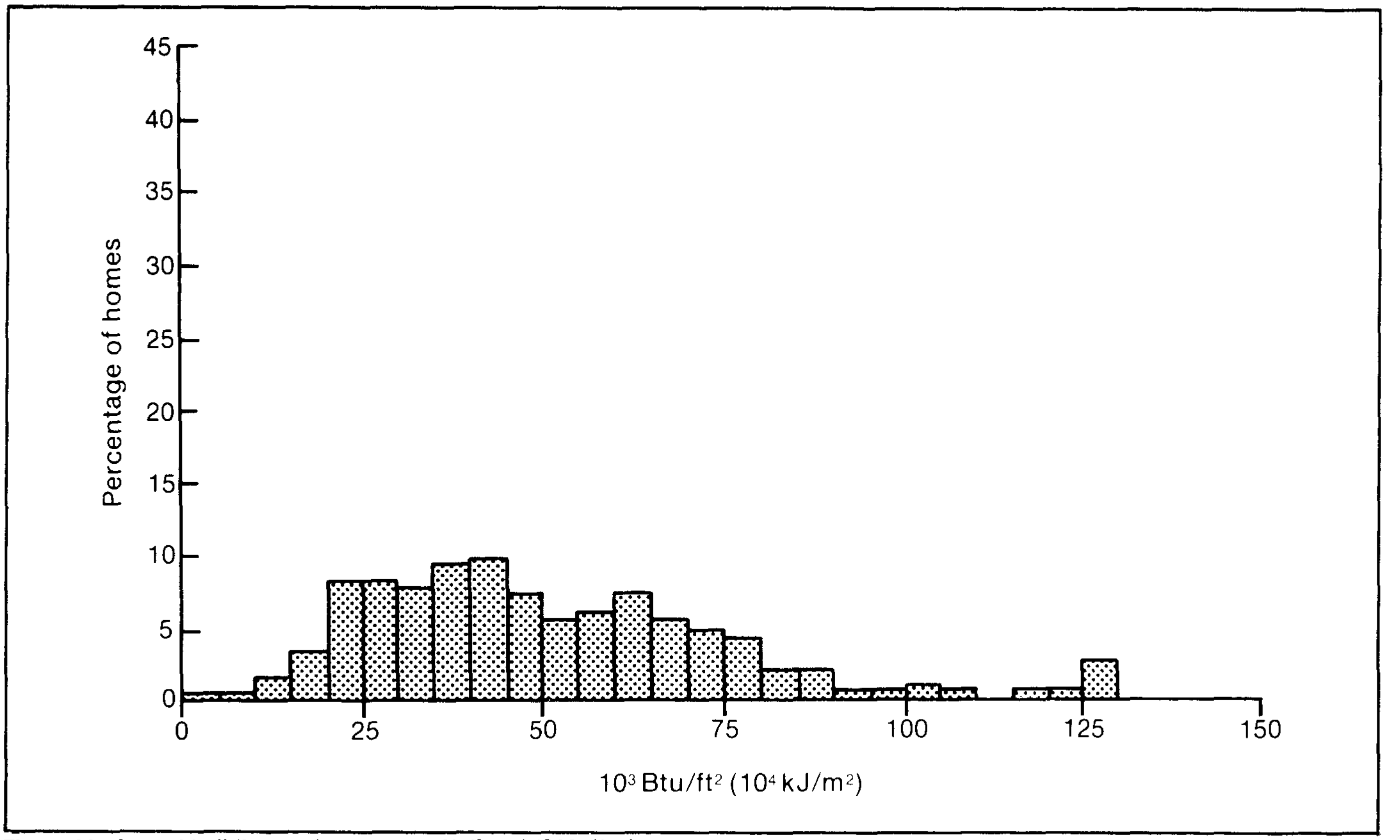

Figure 23. Annual building performance — National (244 sites)

sites. Table 14 presents the BPI for selected variables. The mean BPI is 47.3 x 10^3 Btu/ft^2 (53.7 x 10^7 J/m^2) for all sites. The highest regional value is 54.0 x 10^3 Btu/ft^2 (61.3 x 10^7 J/m^2) in the Northeast, and the lowest is 38.0 x 10^3 Btu/ft^2 (43.1 x 10^7 J/m^2) in the West.

The relatively large standard deviation for sites in the Northeast (28.4) suggests a greater variability in how successful passive solar buildings in this region are at achieving low purchased energy consumption. The histogram of BPI for this region (Figure 19) illustrates this suggestion, showing a cluster of sites with very high BPIs. Inspection of the individual audits for these sites reveals that most of them were homes where the auditors noticed major flaws in design or construction. In most cases, such homes used new designs or approaches to passive solar buildings.

Homes where wood is the primary auxiliary heating source use more purchased energy than other passive homes did, probably because of the lower efficiency of wood stoves.

Sites with lower normalized loss factors (NLF) used less purchased energy than those with higher NLFs. As might be expected, this indicates that heat loss significantly affects the performance of passive solar homes. Building performance did not appear to be related to solar access: sites with restricted solar access use no more energy than those with good access, suggesting that their designs compensated for this limited solar access.

Comparing the BPI of passive solar and nonsolar homes would be very desirable. Unfortunately, at the time of the study, the data were not available. In any case, the results reported here provide a useful yardstick against which designers and analysts can compare the performance of other solar and nonsolar homes.

Table 14. Building Performance Index for Selected Variables

Variable	Number of Sites	Mean BPI 10^3 Btu/ft^2 (10^7 J/m^2)	Standard Deviation
All sites	244	47.3 (53.7)	23.4
Northeast	86	54.0 (61.3)	28.4
Mid-America	56	43.4 (49.3)	20.8
South	66	47.6 (54.0)	18.6
West	36	38.0 (43.1)	17.5
Sites with active systems	18	47.9 (54.4)	20.1
Normalized loss factor 0-0.3 Btu/ft^2 hr°F (0-6.1 kJ/m^2 h °C)	176	44.6 (50.6)	22.7
Normalized loss factor 0.3-1.0 Btu/ft^2 hr°F (6.1-20.4 kJ/m^2 h °C)	73	54.3 (61.6)	23.5
Restricted solar access	19	46.8 (53.1)	17.8
Sites with wood heat	146	54.2 (61.5)	22.9

Data from audit, item 24.

Summary

Trained auditors conducted the technical portion of the Class C audits on passive solar homes in the United States. Virtually all the homes included in the sample were less than 5 years old at the time of the audit, most with good solar access. The homes were, on the average, larger than the mean size of single-family homes in the country. Most homes had lower than expected aperture-to-floor-area ratios and high levels of insulation.

The most common type of passive system found in Class C homes was direct gain, including south-facing windows and sunspace systems. Most of the homes had thermal storage mass of some type, with mass flooring the most frequently used. Over one third of the buildings, however, did not incorporate additional thermal storage mass. Most sites were cooled by direct convection, using windows and vents as well as shading. Virtually all the homes had auxiliary heating systems; wood was the preferred auxiliary heating fuel. Electricity was also used frequently, probably owing to its flexibility in use for zone heating and low initial cost.

The mean indoor temperature for the sites was 65.5°F (18.6°C) in the daytime and 63.1°F (17.3°C) at night. Mean indoor temperatures did not vary by region. Many Class C sites did not have thermostats, so indoor temperature measurements may be imprecise. Total purchased energy in these homes was found to be lower than averages for houses in the United States in all regions except the South. The building performance index computed for the Class C homes showed variable levels of building performance.

Sites in the Northeast tended to have greater variability in performance; lower performance appeared to be related to use of wood as an auxiliary fuel and higher calculated heat loss. Solar access and presence of an active system appeared unrelated to building performance. No comparison of building performance of Class C homes with nonsolar homes was possible owing to lack of data.

Occupant Questionnaire Findings

Introduction

Of the 335 homes included in this portion of the Class C study, 84% (282) were originally designed to incorporate solar features, and 16% (53) had passive or hybrid solar features added after the home was built. Because the performance of homes built with passive solar elements differs substantially from that of retrofit homes, the occupant findings include only data from houses originally designed with solar features. The occupants answered questions on the following:

- Factors affecting their decision to purchase a passive solar home or retrofit
- Information sources they used prior to the purchase decision and their perceived utility
- Problems they encountered with the systems or homes, their severity, and actions taken to correct them
- Perceived passive system contribution to heating needs
- Overall satisfaction level with system performance
- Demographics.

Homeowner Sample

The sites represent a purposive sample of early passive solar homeowners; therefore, findings cannot be generalized to any population of passive solar homeowners. The homeowners participating in the Class C program were typically younger, better educated, and had higher incomes than homeowners included in the RECS survey. This would be expected to characterize innovators and early adopters of technological innovations.* Data from this sample are compared with data from SERI's national probability sample of homeowners collected in the fall of 1980 (Farhar-Pilgrim and Unseld 1982). This comparison shows the distinction between this sample and a representative sample of all the nation's homeowners.

As Table 15 shows, 80% of the homeowners are 45 years of age or younger. In contrast, the SERI and RECS surveys report that 41% of homeowners are under age 45. Class C homeowners are well educated (Table 16). More than 77% are college graduates, a sharp contrast to the 22% found in the SERI study, and 56% have pursued at least some graduate study, as compared with 9% of homeowners in the nation. Table 17 shows that 73% of the Class C homeowners had annual household incomes exceeding $20,000. The RECS study shows only 50% of single-family homeowners earn more than $20,000, and the SERI study shows 53%. Nearly a third of those in the Class C study had annual household incomes exceeding $40,000.

Table 15. Age of Homeowners

Age Range	Homeowners %	Homeowners N
18-20	3	(7)
21-30	13	(37)
31-45	64	(177)
46-65	18	(50)
Over 65	2	(5)
Totals	100	(276)
Missing data		(6)
Total N		(282)

Data from occupant questionnaire, item 58.

*The characteristics of innovation adopters have been studied thoroughly (Rogers and Shoemaker 1971). The first 2.5% of the population to adopt a technical innovation are "innovators," the leading edge of adopters. Next, a group of about 13.5% is defined as "early adopters," those who benefit from the experience of innovators, maximizing their advantages in adopting the innovation, while minimizing their risks. Early adopters are frequently opinion leaders and thus serve as an important social catalyst to shift the innovation's penetration from the select few to the "early majority" (34%). Gradually, the "late majority" (34%) adopts the innovation, for not to do so would leave them more or less behind relative to everyone else. Finally, the "laggards" (16%) get around to adopting the innovation after it is unlikely that they will derive much benefit from doing so, or they never adopt at all (Farhar-Pilgrim and Unseld 1982, p.2).

Table 16. Education Level of Homeowners

Education Level	Homeowners %	N
Some high school	1	(1)
High school graduate	4	(10)
Some college/trade	17	(48)
College graduate	22	(62)
Post graduate work or graduate degree	56	(155)
Totals	100	(276)
Missing data		(6)
Total N		(282)

Data from occupant questionnaire, item 58.

Table 17. Household Income

Annual Household Income[a]	Homeowners %	N
Less than $10,000	3	(8)
$10,000-$19,999	20	(55)
$20,000-$29,999	22	(58)
$30,000-$39,999	22	(59)
Over $40,000	33	(90)
Totals	100	(270)
Missing data		(12)
Total N		(282)

Data from occupant questionnaire, item 60.

[a]1980 data.

Class C homeowners were very involved in the design and construction of their homes. Results indicate that 53% contributed to the design and more than 45% took part in the construction of their homes. These variances show a marked difference between the average single-family homeowner and those in the sample, further supporting the hypothesis that the families in this sample are trend-setters.

The Passive Solar Homes

Architectural styles. Virtually all of the homes (97%) were single-family detached. Approximately 2% were row or townhouses, and about 1% were duplexes. More than 75% of the sample homes were custom built (indicating the unique situation of early passive solar adopters) (Table 18). Almost half of the sample homes were contemporary in architectural style, with the other half distributed across a wide range of architectural styles (Table 19). About a quarter of the owners responded that their homes did not represent any of the standard styles, illustrating the extent of experimentation and design diversity in these early passive solar homes.

Table 18. Home Fabrication

Construction Type	Homes %	N
Custom built	76	(254)
Speculation built	9	(30)
Semi-custom	7	(23)
Renovation	5	(16)
Other	2	(6)
Don't know	1	(4)
Totals	100	(333)
Missing data		(2)
Total N		(335)

Data from occupant questionnaire, item 3.

Perceived market values. Of the 23 owners who bought their homes before 1976, 61% believed that the value of their homes in 1980 was from $40,000 to $79,000, while 30% believed the value to be higher and 9% believed it to be lower. Well over half of the owners who bought between 1976 and 1980 perceived the value of their homes to be $80,000 or higher (Table 20).

Because they knew the original cost of the home, only respondents who were first occupants were asked about changes in its market value. As shown in Table 21, more than 51% of the occupants perceived an increase in property value since the time of purchase. None perceived a loss in property value.

Table 19. Architectural Style

Architectural Style	Homes %	N
Contemporary	45	(144)
Ranch	14	(45)
Salt box	7	(21)
Cape Cod	4	(12)
Earth-shelter	3	(10)
Farm house/building	2	(6)
Colonial	1	(4)
Other	24	(77)
Totals	100	(319)
Missing data		(16)
Total N		(335)

Data from occupant questionnaire, item 4.

Table 20. Perceived Property Value at Time of Audit by Year of Purchase

Perceived Current Market Value	Year of Original Purchase: Through 1977 %	N	1978 %	N	1979 and Later %	N	Total %	N
Up to $39K	6	(4)	4	(3)	2	(3)	3	(10)
$40 - 79K	42	(26)	31	(23)	20	(25)	28	(74)
$80 - 119K	26	(16)	28	(21)	33	(42)	30	(79)
$120 - 159K	15	(9)	27	(20)	24	(31)	23	(60)
≥ $160K	11	(7)	10	(8)	21	(27)	16	(42)
Totals	100	(62)	100	(75)	100	(128)	100	(265)
Missing Data								(17)
Total N								(282)

Data from occupant questionnaire, items 5 and 6.

Table 21. Perceived Change in Property Values

Perceived Market Value at Time of Audit	Original Purchase Price: Up to $39K %	N	$40-$79K %	N	$80-$119K %	N	$120-$159K %	N	≥ $160K %	N	Total %	N
Up to $39K	28	(11)	0	(0)	0	(0)	0	(0)	0	(0)	4	(11)
$40 - 79K	56	(22)	50	(51)	0	(0)	0	(0)	0	(0)	26	(73)
$80 - 119K	13	(5)	41	(42)	48	(37)	0	(0)	0	(0)	31	(84)
$120 - 159K	3	(1)	8	(8)	49	(38)	42	(16)	0	(0)	23	(63)
≥$160K	0	(0)	[a]	(1)	3	(2)	58	(22)	100	(18)	16	(43)
	100	(39)	99	(102)	100	(77)	100	(38)	100	(18)	100	(274)

Data from occupant questionnaire, items 5 and 6.

Shaded area represents those homeowners who perceived an increase in value.

[a]Insignificant percentage.

Interestingly, though, as Table 22 shows, less than 20% of the Class C homeowners thought that increased value of the home was a "very important" factor in their original purchase decision.

Because property values have increased markedly in most parts of the United States since 1979, most homeowners would probably indicate an increase in the market value of their homes. Nevertheless, the passive solar homeowners in this sample are probably at least as likely as, if not more likely than, other homeowners to see their homes as having increased value. To speculate, they may in part be judging that, given escalations in the price of purchased energy since the late 1970s, their energy-efficient homes may have even more value than they would have had otherwise.

Factors Affecting the Purchase Decision

More than three-quarters of the Class C homeowners had passive solar features in mind when they began to look for homes. The 1980 SERI survey found that about two-thirds of U.S. homeowners had at least heard of passive solar energy (Farhar-Pilgrim and Unseld 1982). But only 17% had actually seen a passive solar building. It appears that, from the

Table 22. Factors Affecting the Decision to Purchase Passive Solar Home

Item	% Very Important	% Somewhat Important	Total %	Total N
Save on fuel costs	74	16	90	(265)
Use renewable energy sources	64	21	85	(272)
Provide attractive living environment	59	25	84	(272)
Protect family against fuel shortages	56	26	82	(273)
National energy conservation	50	31	81	(272)
Provide more comfortable environment	47	34	81	(275)
Luxury of warm rooms without extra cost	44	36	80	(272)
Provide daylighting	40	35	75	(269)
Being close to nature	34	34	68	(272)
Floor design	29	32	61	(270)
Wanted greenhouse for food production	23	26	49	(259)
Exterior appearance	21	36	57	(272)
Total N = 282				

Data from occupant questionnaire, item 30.

Only items considered "very important" by more than a fifth of the sample are included. Data are not shown for the following factors listed: recovery time for cost of passive solar features, hobby interest, and increase value of house.

outset, the Class C homeowners were better informed about passive solar energy systems than were homeowners in general.

Actually, two different types of passive solar homeowners can be discerned in the Class C sample. One type bought a home because of its passive solar features. The second type did not specifically seek out a solar home. Of the first group, 60% said they *would not consider* buying a home unless it had passive features. Two-thirds of the second type, however, said they would be willing to buy a nonsolar home (Table 23). These results suggest that the first type feels more strongly about owning a solar home than does the second type. Of the total sample, over half would buy *only* a solar home.

The perspectives of the second type of Class C homeowners may provide some insight into the factors affecting purchase decisions of those buying passive solar homes in the next several years. As the passive solar home industry grows over the next decade, solar homes will need to be sold to people who do not initially intend to buy a home with solar features, although other studies indicate that homebuyers are likely to be concerned about energy efficiency and energy costs. The design, cost, and performance characteristics that could appeal to prospective homebuyers may be relevant in how future homebuyers respond to passive solar homes.

In deciding whether to buy a passive solar home instead of a conventional home, homebuyers consider many factors. Class C homeowners were asked to evaluate the importance of several factors that could have influenced their purchase decisions. Table 22 summarizes the responses. Homeowners placed the greatest importance on the economic benefits. Those benefits can be seen in both a direct benefit to the occupant (saving on fuel costs) and an indirect benefit (national energy conservation and protection from energy shortages). The less obvious economic benefits were tied to the increase in comfort, such as having an attractive, comfortable environment, and the luxury of warm rooms without extra cost. Two economic factors not considered very important were increasing the value of the house and payback period. The factors considered less important tended to be those that were not necessarily tied directly to the use of passive solar energy such as floor design, exterior appearance, daylighting, a greenhouse, and being close to nature. The study suggests that buyers of passive homes were more interested in the comfort and cost savings/availability of fuel than other possible factors.

An interesting pattern emerges when the responses of those who originally intended to buy a passive solar home are compared with those who did not. The first type was somewhat more likely than the

Table 23. Intention to Buy Similar Nonsolar Home

Intention to Buy	Originally Intended to Buy Solar %	N	Did Not Originally Intend to Buy Solar %	N	Total
Would buy similar conventional home	40	(82)	66	(38)	(120)
Would not buy similar conventional home	60	(122)	34	(20)	(142)
Totals	100	(204)	100	(58)	(262)
Missing data					(20)
Total N					(282)

Data from occupant questionnaire

second type to rate noneconomic comfort and aesthetic factors as important; being close to nature, using renewable energy sources, and providing an attractive environment were somewhat more important to those who originally intended to purchase a passive solar home (Table 24). Assuming that future homeowners' behavior might be consistent with that of the second type of passive solar owner, one can surmise that they are likely to place greater value at first on the economic assets of passive solar design, such as fuel cost savings and protection from interrupted fuel supplies, and slightly less importance on noneconomic factors.

Information Sources

Respondents were presented with a list of potential information sources and asked where they "first got the idea of having a passive solar home." They were instructed to check as many sources as applied. Table 25 presents the most frequently mentioned sources, including published media (books, magazines, and newspapers) and interpersonal contact (friends, architects, and solar workshops). Responses citing publications occurred almost twice as frequently as those citing interpersonal contact, with books receiving the highest response.

The second question on information sources examined the usefulness of the sources used for "information or help in planning or learning about" their passive solar home (Table 26). As in the previous question, books (77%), magazines (73%), and individuals (61%) were cited most often. Although solar seminars or conferences were attended by only 34% of the group, they were

Table 24. Original Purchase Intention by Selected Decision Factors

Decision Factors[a]	% Originally Intended to Buy Passive Home	% Did Not Originally Intend to Buy Passive Home	Total
Use renewable energy sources	71	50	
Provide more comfortable environment	64	44	
Being close to nature	39	24	
Totals	207	55	(262)
Missing data			(20)
Total N			(282)

Data from occupant questionnaire, item 15.

[a]Ranked as "very important" or "somewhat important."

considered the most useful. Books and individuals followed solar seminars in terms of usefulness. Newpapers were considered least helpful.

Perceived Passive Solar Contribution to Heating Needs

In the questionnaire, occupants were asked the following three questions about solar contribution to their heating needs:

- When the passive solar features of your home were designed, what percentage of your annual heating needs did you expect them to provide?
- For the last year, how much of your heating needs were supplied by your passive solar systems?
- Thinking ahead to next year, what percentage of your heating needs do you anticipate being supplied by the passive solar features of your home?

Table 27 shows the responses to these three questions. About 30% expected that their passive solar features would contribute up to 40% of their heating needs, and a similar proportion reported that their systems had performed that well in the previous year. Over half the sample (54%) expected their systems to supply between 40% and 80% of their heating needs and a nearly identical proportion (53%) said that their systems did indeed perform that well in the last year. About one in six of the sample expected their systems to supply most to all of their

Table 25. Source of Initial Idea of Purchasing a Passive Solar Home

Source[a]	Homeowners Citing Source[b] %	N
Book	58	(164)
Magazine	45	(126)
Friend or other person	29	(81)
Architect	23	(65)
Newspaper	22	(61)
Solar workshop or conference	22	(61)

Data from occupant questionnaire, item 20.

[a]Only sources cited by 20% or more of homeowners are included in the table.

[b]Numbers and percentages reflect multiple responses.

Table 26. Perceived Utility of Passive Solar Information Sources

Source	Very Useful %	N	Somewhat Useful %	N	Not Very Useful %	N	Total %	N	Mentioned Source %	N
Books	66	(137)	32	(66)	2	(5)	100	(208)	77	(216)
Magazines	35	(69)	60	(120)	5	(11)	100	(200)	73	(207)
Individuals	60	(97)	38	(62)	2	(3)	100	(162)	61	(172)
Solar seminars or conferences	69	(61)	28	(25)	3	(3)	100	(89)	34	(95)
Government publications	21	(23)	55	(59)	24	(26)	100	(108)	39	(111)
Library reference material	41	(36)	48	(42)	11	(10)	100	(88)	33	(92)
Newspapers	10	(9)	55	(51)	34	(32)	100	(92)	33	(93)
Government agencies	23	(10)	42	(18)	35	(15)	100	(43)	16	(44)

Data from occupant questionnaire, item 25.

Table 27. Expected, Perceived, and Anticipated Passive Solar Contributions to Heating Needs

Perceived Percentage of Total Heating Need Contributed by Solar	Estimated Passive Solar Contribution					
	Expected		Perceived		Anticipated	
	%	N	%	N	%	N
<40	30	(81)	30	(78)	27	(70)
40-59	28	(73)	26	(69)	24	(62)
60-79	26	(68)	27	(71)	28	(74)
80-100	16	(42)	17	(45)	21	(56)
Totals	100	(264)	100	(263)	100	(262)
Missing data		(18)		(19)		(20)
Total N		(282)		(282)		(282)

Data from occupant questionnaire, item 35.

heating needs and a nearly identical proportion reported that their system supplied 80% to 100% of their heating needs in the last year of operation.

Expectations for the performance of these systems appeared to increase slightly with experience. The percentage anticipating a less-than-40% contribution declined by three points; the percentage anticipating a contribution of 40% to 80% declined by one point, and the percentage anticipating most to all heating needs to be supplied by their system increased by four points.*

It appears that the Class C passive solar homes are performing at least as well as their owners expected, and that these owners anticipate even better performance as they become more familiar with their homes.

Most Class C homeowners (76%) used direct gain as their main passive solar system. The second and third most prevalent systems were storage/collection wall systems (10%) and isolated storage walls (8%). A very small number of other system types were represented in the study (Table 6). Table 28 presents data on the expected, perceived, and anticipated system contribution to heating needs by direct gain and the two types of storage systems combined. Both owners of direct gain and of storage systems displayed the same pattern identified for the sample as a whole: they expected improved system performance after living with the system for at least a year. However, owners with storage systems had even higher expectations for system performance than owners of direct gain systems. While 43% of those with direct gain systems expected their systems to contribute 60% or more of their heating needs, 52% of those with storage systems expected this level of thermal performance. Furthermore, 63% of storage system owners reported that 60% or more of their heating needs were met in the last year by their passive systems, compared with 43% of the direct gain owners. More than two-thirds of the storage system owners anticipated that 60% or more of their heating needs would be met in the coming season — a gain of 17 points over original expectations — compared with 49% of direct gain owners —representing a gain of 6 points over their original expectations. Thus, the performance of storage systems in particular, as judged by the Class C homeowners, exceeded expectations rather markedly. The performance of direct gain systems was apparently closer to expectations, which still increased slightly with experience.

Although one can only speculate, increasing expectations for thermal performance could be related to the fact that so many of the study participants were involved with the building of their homes. Because many of the homes were early examples of passive solar design, mistakes were sometimes made. In some cases these mistakes were recognized but not corrected before the audit. Other homes were not totally finished at the time of the audit — they still needed shutters installed, or the basement insulated, for example. Also, homeowners who had been involved with the design and construction of their homes may have anticipated improved performance as they became more familiar with their systems. (For those homes equipped with manual controls for the passive systems, such as for opening thermal shutters or turning on fans, good performance depends on the occupants' effective participation.)

*These findings are for the sample taken as a whole; there may be individuals within the sample whose expectations were not met or were exceeded by their experience with their passive solar home.

Table 28. Expected, Perceived, and Anticipated Solar Contribution to Heating Needs by Three System Types

% of Total Heating Need Contributed By Solar	Passive Contribution											
	Direct Gain						Storage/Collection Wall or Isolated Storage Wall					
	Expected		Perceived		Anticipated		Expected		Perceived		Anticipated	
	%	N	%	N	%	N	%	N	%	N	%	N
<40	32	(63)	31	(60)	27	(52)	23	(11)	20	(9)	18	(8)
40-59	25	(50)	26	(51)	24	(47)	25	(12)	17	(8)	13	(6)
60-79	27	(53)	26	(51)	27	(52)	27	(13)	37	(17)	40	(18)
80-100	16	(31)	17	(34)	22	(43)	25	(12)	26	(12)	29	(13)
Number (N)	100	(197)	100	(196)	100	(194)	100	(48)	100	(46)	100	(45)

Data from occupant questionnaire, item 35.

Problems Encountered in Passive Solar Homes

By evaluating the frequency and severity of problems in passive solar homes, occupants can provide valuable feedback about performance. Class C homeowners were asked to comment on two kinds of problems: (1) problems encountered in the primary living space, which is defined in this study as all areas that are maintained within 10°F (5.6°C) of the main living area and (2) problems encountered in buffer spaces, those areas of the home (primarily sunspaces) that have temperature fluctuations of greater than 10°F (5.6°C).

Problems in the Primary Living Space

Class C program designers assumed that overheating in the primary living space could be a major problem in passive solar homes. Overheating was therefore addressed separately in the questionnaire, focusing on details about season, frequency, and severity of occurrence. Highlighting the overheating problem in the questionnaire may have biased the results more in the direction of increased response than if overheating had just been listed along with other potential passive system problems. Whatever the bias may have been, overheating (treated as a special concern) and keeping windows and glass areas clean (from a list of possible problems) were both cited as problems by 46% of the respondents answering the items. More than half (54%) reported no problems with overheating (Table 29).

Table 30 summarizes the data on the seasons of the year when overheating tends to occur, the level of discomfort occupants experienced by season, and the mean number of days per season that overheating occurred. Of responses mentioning problems, those who experienced overheating said it occurred most frequently in the summer (38%) and winter (30%) with spring and fall the least likely times for a house to overheat. Of responses mentioning discomfort, 85% rated it as "somewhat uncomfortable" and 15% as "very uncomfortable." Most discomfort was reported in the summer and second most in the winter, coincident with the periods most likely to overheat. Similarly, the mean number of days during which overheating occurred was highest for summer (12.44) and lowest for fall (7.59).

Following the in-depth questions about overheating, respondents were asked to rate the seriousness of 17 other potential problems with passive systems (Table 31). Problems mentioned most frequently were keeping windows and glass areas clean (46% of those mentioning problems), condensation on windows (41%), and glare (34%). The remainder of the listed problems were cited by fewer than a quarter of the Class C homeowners mentioning problems and fewer than a fifth of the sample as a whole.

Of those mentioning any particular problem, the tendency was for them to see it as somewhat serious. A few owners (varying from 1 to 15 by item) considered some of the problems "very" serious.

Table 29. Overheating Problems in Primary Living Space Due to Passive Solar System

Overheating Due to Passive Solar	Homeowners %	N
Yes	46	(127)
No	54	(148)
Totals	100	(275)
Missing data		(7)
Total N		(282)

Data from occupant questionnaire, item 43.

Table 30. Overheating Problems by Season

Season	Mentioning Overheating %	Mentioning Overheating N	Very Uncomfortable %	Very Uncomfortable N	Somewhat Uncomfortable %	Somewhat Uncomfortable N	Discomfort Total %	Discomfort Total N	Mean No.[b] of Days
Summer	38	(71)	59	(13)	41	(54)	45	(67)	12.44
Fall	17	(32)	18	(4)	17	(22)	17	(26)	7.59
Winter	30	(55)	9	(2)	26	(33)	23	(35)	8.52
Spring	15	(28)	14	(3)	16	(20)	15	(23)	8.33
	100	(186)[a]	100	(22)	100	(129)	100	(151)[a]	

Data from occupant questionnaire, item 44.

[a]N is greater than the 127 respondents mentioning overheating as a problem due to multiple responses. There were 28 responses that overheating was not at all uncomfortable.

[b]Means calculated from responses to item 44c.

Table 31. Problems with Solar Features Experienced in Primary Living Space

Problem	Very Serious %	Somewhat Serious %	Not Very Serious %	Total[a] %	Total[a] N
Keeping windows/glass areas clean	3	20	16	40	(113)
Condensation on windows	5	15	15	36	(101)
Glare	3	13	13	30	(84)
Fading of furniture/walls/coverings	1	12	6	20	(57)
Excessive humidity	5	9	5	20	(56)
Problems with weatherstripping or caulking	5	9	5	20	(55)
Drafts	5	9	5	18	(52)
Not warm enough	1	11	5	18	(52)
Rooms cool down too fast	2	10	4	17	(47)
Extreme temperature swings	1	10	2	15	(42)
Lack of privacy	1	7	6	15	(41)
Mechanical/electrical system failures	5	4	2	12	(35)
Stagnant odors	1	4	3	8	(23)
Covering sloped windows	2	4	1	7	(19)
Building codes	1	2	1	5	(13)
Assured solar access	0	2	1	4	(10)
Zoning restrictions	0	1	1	2	(5)
Other problems	3	5	1	10	(29)

Data from occupant questionnaire, item 46.

[a]Numbers and percentages reflect multiple responses.

The two most frequently mentioned problems — overheating and keeping glass clean — are somewhat different in their effect on homeowners. Overheating causes discomfort while keeping glass clean can be an inconvenience. Experiencing overheating may have contributed to owner perception of high system thermal performance.

The problems are quite varied, as are their causes. Some problems appear to be related to the design of the house; others are more a result of the quality of construction. Overheating is a specific design problem experienced by many respondents. The problems of keeping glazings clean, excessive glare, lack of privacy, and fading of furnishings are also related to the house design. Condensation and excessive humidity may be caused by construction problems, climate, or poor design. Problems with seals (weatherstripping/caulking) and mechanical/electrical systems are related to materials and equipment malfunction or faulty installation. Comments about the house not being warm enough or rooms cooling too quickly may reflect homeowners' disappointment with system performance, but this discontent is complicated by the fact that they may have had unrealistic expectations about what a particular system could deliver. Zoning and building code issues are not performance problems of solar homes, but were included in the questionnaire to determine whether they had been perceived as significant obstacles to acquiring passive solar homes.

Problems in Buffer Spaces

Because greenhouses, sunspaces, and other buffer areas may develop problems different from those experienced in the primary living space, a separate set of questions addressed them. Nearly half of the Class C homeowners (43%) had one or more buffer spaces in their homes. Of the buffer spaces identified, 60% were greenhouses, 20% were sunspaces, and 20% were other types. The definition of a greenhouse used in this study is a south-facing room where plants are grown the majority of the year. A sunspace, on the other hand, does not have plants, and its temperature is allowed to fluctuate more than that of a greenhouse.

Respondents were asked to identify and rank the seriousness of listed problems in their buffer spaces. Table 32 summarizes the data. Among owners of buffer spaces, 53% reported problems with overheating and 31% with keeping glass clean. Other problems were cited by fewer than a fifth of these owners. As with problems cited for the primary living space, owners having problems tended to view them as "somewhat" serious.

Convenience of Operation and Maintenance of Manual Components

Manually operated components play an important part in the performance of many passive solar homes. The thermal performance of the home can be greatly reduced if these components are not used properly. Researchers wanted to know how often the components were used and whether homeowners considered them to be inconvenient. To address these issues, occupants were asked about the level of inconvenience they encountered with the components. Table 33 shows types of components and the proportion of homes with them. About half of the Class C homes had shades, fans, and vents, and more than a quarter had movable insulation. Most of these components were manually operated.

Table 34 shows how the occupants assessed the inconvenience of operating the components. Fans requiring manual operation seemed to cause the least inconvenience. Over half the homeowners with these features did not consider shades, sunscreens, or vents to be inconvenient. Movable insulation and reflector panels were considered "somewhat" or "very" inconvenient by 51% and 50% of those operating this component, respectively.

In response to the question of whether they found the manual systems too inconvenient to operate at all, few people said they did. In the case of manually

Table 32. Problems with Greenhouses, Sunspaces, and Other Buffer Spaces

Problem	Very Serious %	Somewhat Serious %	Not Very Serious %	Total[a] %	Total[a] N
Overheating	11	28	14	53	(64)
Requires too much backup heat	2	4	2	8	(10)
Condensation	2	10	5	18	(22)
Keeping glass clean	2	17	12	31	(38)
Other problems	2	5	1	9	(11)

Data from occupant questionnaire, item 49.

Table 33. System Components and Manual Operation

Component	Have Component[a] %	N	Have Manual Component[b] %	N
Shades/other sunscreening devices	55	(155)	79	(123)
Fans	53	(148)	51	(76)
Vents	49	(138)	78	(108)
Movable insulation	28	(79)	92	(73)
Reflector panels	5	(13)	77	(10)
Other	9	(26)	81	(21)

Data from occupant questionnaire, item 57.

[a]Represents the percentage that have the component, based on the total sample of 282.

[b]Represents the percentage that consider the component to be manual, based on the total of those having the component.

Table 34. Degree of Inconvenience of Manual Components[a]

Component	Not at All Inconvenient %	N	Somewhat Inconvenient %	N	Very Inconvenient %	N	Total N[b]
Fans	77	(57)	16	(12)	7	(5)	(74)
Vents	55	(58)	40	(42)	5	(5)	(105)
Shades/other sunscreens	51	(63)	42	(52)	7	(8)	(123)
Movable insulation	39	(28)	47	(34)	14	(10)	(72)
Reflector panels	20	(2)	50	(5)	30	(3)	(10)
Other	53	(10)	31	(6)	16	(3)	(19)

Data from occupant questionnaire, item 57.

[a]Represents the number of occupants with the component who consider it to be manual based on a total sample of 282, less missing data.

[b]Numbers reflect multiple responses.

operated vents, only 5% of those people who had them found them to be too inconvenient to operate. No more than 1% of those who had any of the other specific components found them to be too inconvenient to use.

Occupant Satisfaction with Passive Solar Homes

Table 35 shows that most Class C homeowners were "very satisfied" (89%) with their passive solar homes and another 11% were "somewhat satisfied." No homeowners expressed dissatisfaction with their homes.

Respondents were asked about their degree of satisfaction with a list of 11 aspects of their homes. Table 36 presents the data, which are organized in order of decreasing satisfaction levels. Respondents were most positive about the interior and exterior designs, floor plans, and energy cost savings. Comfort levels, effort and time required in daily operation, and general maintenance requirements were also satisfactory. Although respondents were in general satisfied with all aspects listed, they gave lower ratings to cooling distribution and humidity control.

Perceived system thermal performance was cross tabulated by degree of satisfaction with the home (Table 37). Respondents whose homes met or exceeded expectations were highly satisfied with their homes. Even among respondents whose expectations for thermal performance were not met by their experience with their systems, 81% said they were "very satisfied," and 19% said they were "somewhat satisfied."

Table 35. Overall Level of Satisfaction With Passive Solar Home

	Level of Satisfaction %	N
Very satisfied	89	(248)
Somewhat satisfied	11	(31)
Not at all satisfied	0	(0)
Totals	100	(279)
Missing data		(3)
Total N		(282)

Data from occupant questionnaire, item 36.

Table 36. Degree of Satisfaction with Specific Aspects of Passive Solar Home

	Very Satisfied		Somewhat Satisfied		Not at All Satisfied		Don't Know		Total
Aspect	%	N	%	N	%	N	%	N	N
Interior design	87	(198)	13	(30)	[a]	(1)	0	(0)	(229)
Floor plan	85	(196)	14	(33)	[a]	(1)	0	(0)	(230)
Exterior design of house	79	(222)	20	(57)	0	(0)	[a]	(2)	(281)
Energy cost savings	78	(218)	21	(59)	[a]	(1)	0	(0)	(278)
Effort/time required in daily operation	74	(207)	23	(64)	[a]	(3)	2	(5)	(279)
General maintenance requirements	71	(198)	26	(72)	1	(4)	2	(5)	(279)
Comfort level	71	(198)	28	(78)	[a]	(1)	[a]	(1)	(278)
Heat distribution	58	(161)	39	(110)	3	(8)	0	(0)	(279)
Performance of mechanical components	54	(138)	25	(64)	4	(11)	16	(41)	(254)
Cooling distribution	38	(101)	43	(115)	5	(14)	14	(39)	(269)
Humidity control	35	(97)	41	(112)	8	(22)	16	(43)	(274)

Data from occupant questionnaire, item 39.

[a]Less than 0.05%.

Table 37. Perceived System Performance by Degree of Satisfaction

Level of Satisfaction	Performance: Exceeded Expectations by ≥ 10%		Equalled Expectations		Did Not Meet Expectations by ≥ 10%		Total
	%[a]	N	%[a]	N	%[a]	N	N
Very satisfied	93	(86)	91	(92)	81	(70)	(248)
Somewhat satisfied	7	(6)	9	(9)	19	(16)	(31)
Totals	100	(92)	100	(101)	100	(86)	(279)
Missing data							(3)
Total N							(282)

Data from occupant questionnaire

[a]Percentages based on response within category

Summary

As would be expected of the early users of new technologies, the Class C homeowners were typically younger, better educated, and had higher incomes than homeowners in general. The majority of them contributed to the design of their homes and 45% actually helped build their homes. The Class C passive solar homes varied architecturally, although the majority of them were contemporary in style.

Both economic and noneconomic factors influenced the sample's purchase decisions. Saving on fuel costs and protection from fuel shortages were the most frequently mentioned economic reasons. An attractive environment, comfort, and national energy conservation were among the most frequently cited noneconomic reasons given for purchasing a passive solar home.

Information sources on solar energy used most frequently by these respondents were books, magazines, and individuals. However, the most useful information sources were solar seminars and conferences, books, and individuals.

Problems with passive systems mentioned most frequently were overheating, keeping windows clean, condensation on windows, and glare. Those mentioning problems tended to view them as moderately troublesome. Owners of greenhouses and sunspaces reported moderate problems with overheating and keeping glass clean.

About half the homes had shades, fans, and vents, while over a quarter had movable insulation. The majority of these components were manually operated. Respondents were divided on how inconvenient these components were to operate; about half of the owners with such features said they were inconvenient to use and the other half did not. Apparently, manually operated components other than fans inconvenience passive homeowners to varying degrees, perhaps depending on their life-styles.

As has been found in other studies of solar owners, most Class C homeowners were very satisfied with their passive solar homes, despite the problems they identified. Characteristics of the homes that pleased them most were exterior design and energy cost savings. As they become more familiar with their homes, the occupants anticipated increased thermal performance.

Most respondents whose homes had met or exceeded expectations for thermal performance were highly satisfied with their homes. Even 81% of respondents whose expectations were not met fully, reported being "very satisfied" with their passive solar home overall.

One of the most telling statistics of the study concerns the purchase of a future home. Of the homeowners that did not originally intend to buy a passive solar home, 34% would not buy a conventional home in the future. Of those who intended to buy a passive home, 60% said in the future they would only buy a passive solar residence.

The Class C owners of passive solar homes are a unique group. They are likely to be highly knowledgeable about their homes; therefore, their expectations for system performance may have been more realistic than those of an average homebuyer. Their experience with their homes prior to the study gave them the opportunity to observe performance and achieve routine interaction with their passive systems. Thus, the high level of satisfaction displayed by the sample is encouraging to the future acceptance of passive solar homes in the United States.

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Appendix A:
Occupant Questionnaire

MARKET FACTS, INC. 100 SOUTH WACKER DRIVE CHICAGO, IL 60606

PASSIVE/HYBRID SOLAR HEATING AND COOLING SYTEMS

CLASS "C" AUDIT FORM

PART 1 - NONTECHNICAL INFORMATION

1. Site Code Number: ______________________ (5-8)

2. Auditor Code Number: ______________________ (9-10)

3. Auditor Name: ______________________

INTRODUCTION

The questions in this survey ask you about general characteristics of your home, more specific questions about your passive solar home and about any problems you may have had. There is also a short section about your personal characteristics to help us combine your answers with those of other people who will be filling out this questionnaire.

Please answer each question by putting an "X" in the block next to the most appropriate answer, or by writing the answer on the lines provided. After some questions, there may be arrows after certain answers asking you to "SKIP" to other questions. When you have chosen an answer with such an instruction, be sure to put an "X" beside your answer before going on to the question indicated in the "SKIP" instruction.

Please complete all questions that apply to your situation. Do not leave blank spaces unless you are instructed to "SKIP". Give estimates where exact figures are not available.

Your answers to these questions will be used in compiling your responses with other passive solar home owners. Your responses to these questions are confidential.

Thank you very much.

GENERAL INFORMATION

i. Please print full name(s) of person(s) filling out this part of the audit:

a) ______________________

b) ______________________

ii. Indicate the description(s) which applies to you:

Female head of household ... ☐1 Other female ... ☐3 (11)

Male head of household ..... ☐2 Other male ..... ☐4 (12-17)

iii. Date of audit: ____________ ______ ______
month day year

iv. Mailing address: ______________________

____

____

v. Street address (if different from mailing address):

____

____

vi. Phone number: (_____) ______________________

SECTION A: GENERAL CHARACTERISTICS OF YOUR HOME

1. Was this house previously occupied or were you the first occupant?

Previously occupied ..... ☐1
First occupant .... ☐2 (18)

2. Which of the following best describes your house?

Single-family detached .... ☐1
Detached two-family (duplex)... ☐2
Rowhouse/townhouse............ ☐3 (19)
Multifamily Condominium........ ☐4

3a. Which of the following best describes your house?

Custom-built; that is, designed according to your specifications .... ☐1
Semi-custom; you selected an existing design and then had home built .... ☐2
Pre-built/speculation-built .... ☐3 (20)
Other (please describe)
______________________ .... ☐4
Don't know .... ☐5

3b. Was your home pre-fabricated or pre-manufactured?

Yes .... ☐1
No .... ☐2 (21)

4. Which architectural style best describes your house? For example, is it a ranch style, capecod, or some other style? Please describe the architectural style as well as you can.

______________________________________ (22)

5a. What was the initial market value of your house?

$ ____________________ (23-28)

5b. In what year did you buy your house? 19 ☐☐ (29-30)

6. About how much do you think this house would sell for if you sold it today? If you are not sure, please write down your best estimate.

$ ____________________ (31-36)

7. Were the principal features of your passive solar home included in the original design of your house, or were they a retrofit, that is, installed after the house was built?

In the original design ..... ☐1 → (SKIP TO SECTION C) (37)

Retrofit (installed after building)......... ☐2 → (GO ON TO SECTION B)

Auditor Use Only

Constr. Type	Crawl Space	System Type-Heating	System Type-Cooling
(38)	(39)	(40-41)	(42-43)

SECTION B: GENERAL CHARACTERISTICS OF YOUR HOME

Answer this section only if your home has a passive solar retrofit, that is, solar features which were installed after the house was built.

8. Were the passive solar features installed by a previous occupant, or did you decide to install them?

Previous occupant decided .... ☐1 → (SKIP TO SECTION C) (44)

You decided .... ☐2

9. Approximately how much money did you pay for the total home improvement including the passive solar features? Please do not include the value of unpaid labor (such as family and friends, etc.), but only what your family actually paid for labor and materials.

$ ________________ (45-50)

10. Please indicate below:

a) the items which are included in your cost estimate and
b) the approximate cost of each item, even if you included its cost in Question 9.

Item	10a Included in Total Cost? Yes	No	10b Approximate Cost of Item	
Construction labor	☐1	☐2	$ ________	(51-57)
Design labor	☐1	☐2	$ ________	(58-64)
Material	☐1	☐2	$ ________	(65-71)
Other (please describe) ________________	☐1	☐2	$ ________	(72-78)

79 [0][1] 80

11. When you first started thinking about the retrofit to your home, what sort of home improvement did you have in mind? Please choose the one statement below which best describes your initial plans about your retrofit.

We were looking for an addition which would give us extra space. We were not originally thinking of a passive solar retrofit .... ☐1

We were looking for an addition which would give us extra space and which incorporated passive solar features .... ☐2 (5)

We were looking to enhance an existing part of our home. We were not originally thinking of a passive solar retrofit .... ☐3

We were looking to enhance an existing part of our home and which incorporated passive solar features.................... ☐4

We were looking for a plan to make our home more energy conserving. We were not originally thinking of a passive solar retrofit .... ☐5

We were looking for a plan to make our home more energy conserving and which incorporated passive solar features......... ☐6

We wanted to add a greenhouse to our home so that we could grow plants year-round. We were not originally thinking of a passive solar retrofit.. ☐7

We wanted to add a greenhouse to our home so that we could grow plants year-round and help heat our home.................... ☐8

12. If your home improvement provided additional living space: Do you feel that you paid more than you would have if you had made the same improvement without passive solar features?

Yes, paid more for my home improvement by including passive solar features .... ☐1

No, didn't pay more for my home improvement by including passive solar features .... ☐2 → (SKIP TO SECTION D) (6)

Home improvement did not provide additional living space .... ☐3 → (SKIP TO SECTION D)

13. By adding passive solar features to the home improvement, how much more do you think you had to pay than you would have paid for a non-solar addition? That is, approximately what percent of the total cost was due to the passive solar features?

______________% (7-9)

14. Please indicate below the items of the home improvement that cost more because of the passive solar features:

Item

Labor	☐1	Architect/designer fees	☐7
Glazing	☐2	Other (please describe)	
Shades, window insulation, etc.....	☐3	____________________	☐8
Masonry or brick materials	☐4	____________________	
Floor surfaces	☐5	____________________	
Other thermal storage	☐6		

(10)

PLEASE SKIP TO SECTION D.

SECTION C: PASSIVE SOLAR HOME INFORMATION

Answer this section only if your home was built with the passive solar features included.

15. When you were in the market for your current home, did you start out looking for a home that incorporated passive solar design?

Yes, we started out looking for a passive solar home .... ☐1

No, we did not start out with the intention of only buying a home with passive solar design .... ☐2 (11)

16. Would you have chosen a house similar to this one in design and appearance if it did not have passive solar features?

Yes, like the design and appearance regardless of the passive solar features... ☐1

No, would have chosen a different style.... ☐2 (12)

17. Do you fell that you paid more for you passive solar home than you would have for a well-designed home with no passive solar features of approximately the same size in the same location?

Yes .... ☐1

No .... ☐2 ➜ (SKIP TO SECTION D)

Not sure ..... ☐3 ➜ (SKIP TO SECTION D) (13)

18. Approximately how much more do you think you paid for the passive solar features of the home? (Do not adjust for any tax credits you may have received.)

Less than $1,000 .... ☐1	$15,000 to $19,000 ...... ☐5	
$1,000 to $4,999 .... ☐2	$20,000 to $24,000 ...... ☐6	(14)
$5,000 to $9,999 .... ☐3	$25,000 or more .... ☐7	
$10,000 to $ $14,000 .... ☐4		

19. Listed below are some items that sometimes add to the price of a home. Mark an "X" in the box next to those items that you think added to the cost of your home. If there were some items that you think added significantly to the cost of your home but aren't on the list, please write them in.

Principal Cost Items	Added to Cost	
Glazing (windows).........................	☐1	
Shades, window insulation, etc...........	☐2	
Brick or other masonry materials	☐3	(15)
Floor surfaces	☐4	
Fans	☐5	
Other Thermal Storage.....................	☐6	
Other (Please Describe)		
______________________	☐7	
______________________		
______________________		

SECTION D: INFORMATION SOURCES

20. Where did you FIRST get the idea of having a passive solar home? ("X" AS MANY AS APPLY)

- Read about it in a book .... ☐1
- Saw a model or demonstration home .... ☐2
- Friends or other individuals .... ☐3
- Architect suggested it .... ☐4
- Builder suggested it .... ☐5
- Standard plans .... ☐6
- Heard about it on the radio ..... ☐7
- Saw it on television .... ☐8
- Read about it in the newspaper .... ☐9
- Read about it in a magazine .... ☐0
- Solar workshops and conferences ...... ☐X
- Home shows .... ☐R
- Energy shows .... ☐-1
- Adult education classes .... ☐-2
- Other (Please Describe) ________________ ..... ☐-3

(16-18)

21. Who contributed to the design of the principal features of your passive solar home? ("X" AS MANY AS APPLY)

- Contractor .... ☐1
- Architect .... ☐2
- Engineer .... ☐3
- Do-it-yourself .... ☐4
- Standard plans .... ☐5
- Other (Please Describe) ________________ .. ☐6 ________________

(19)

22. Who did the actual construction of your home's passive solar features? ("X" AS MANY AS APPLY)

- Builder .... ☐1
- Sub-Contractor .... ☐2
- Do-it-yourself .... ☐3
- Other (Please Describe) ________________ .. ☐4 ________________

(20)

23. Below is a list of types of people who are sometimes involved in the design of new homes and remodeling projects. When you first considered building your new home, or retrofitting your old one, which of the people listed below:

a) did you consult with about passive solar ("X" AS MANY AS APPLY) and/or
b) suggested passive solar ("X" AS MANY AS APPLY)?
c) Now, for each person you "X"ed in a and/or b, please mark an "X" in the box below to show whether you thought this person was "very" knowledgeable, "somewhat" knowledgeable, or "not very" knowledgeable about passive solar. If some other professional person consulted with you, or suggested passive solar to you, please write in their professional title on the line below and answer the question "c" about them also.

	23a	23b	23c			
	Consulted?	Suggested Passive?	Knowledgeable About Passive?			
	(21)	(22)	Very	Somewhat	Not Very	
Builder(s)	☐1	☐1	☐1	☐2	☐3	(23)
Architect(s)................	☐2	☐2	☐1	☐2	☐3	(24)
Engineer(s)	☐3	☐3	☐1	☐2	☐3	(25)
Real Estate Agent(s)........	☐4	☐4	☐1	☐2	☐3	(26)
Others (Please Describe)						
____________________ ...	☐5	☐5	☐1	☐2	☐3	(27)
____________________ ...			☐1	☐2	☐3	(28)

24a. When you were making a decision about your passive solar home or retrofit, was there any other information you would have <u>liked</u> to have received from the people you consulted with that they were unable to provide?

Yes .... ☐ (29)
No .... ☐ ——► (SKIP TO QUESTION 25a)

24b. What kind of information were they not able to provide?

____

____

____

25a. Below is a list of sources of information you might have used in planning or learning more about your passive solar home. Please mark an "X" in the box beside each source that you or your family used for information or helped in planning or learning about your passive solar home.

25b. For each source that you or your family used, please "X" the box below to show whether you found the source to be "very" useful, "somewhat" useful, or "not very" useful to you or your family.

	25a	25b			
	Did you use this source?	How useful was it?			
Sources	(30-31)	Very	Somewhat	Not very	
Books	☐1	☐1	☐2	☐3	(32)
Magazines	☐2	☐1	☐2	☐3	
Newspaper	☐3	☐1	☐2	☐3	
Library reference material	☐4	☐1	☐2	☐3	
Government publications	☐5	☐1	☐2	☐3	
Government agencies	☐6	☐1	☐2	☐3	
Adult education classes	☐7	☐1	☐2	☐3	
Solar seminars or conferences	☐8	☐1	☐2	☐3	
Individuals	☐9	☐1	☐2	☐3	
Yellow pages	☐0	☐1	☐2	☐3	
Other (please describe)					
______________________	☐X	☐1	☐2	☐3	
______________________		☐1	☐2	☐3	
______________________		☐1	☐2	☐3	(44)

25c. If you used any books or magazines, please list the ones that were most useful to you.

______________________ ______________________
______________________ ______________________
______________________ ______________________
______________________ ______________________

25d. If you used any government agencies (such as Energy Extension Service, Weatherization Program, State Solar Office, Regional Solar Energy Center, National Solar Heating and Cooling Information Center, etc.) for information, please list the ones you used.

______________________ ______________________
______________________ ______________________
______________________ ______________________
______________________ ______________________

26a. During the design and construction of your passive solar home or retrofit, was there any information you would have liked to have had, but were unable to find?

Yes .... ☐ (45)
No .... ☐ ——► (SKIP TO QUESTION 27)

26b. What kind of information were you not able to find?

____

____

____

27a. Do you think your home's passive solar features have raised, lowered or had no effect on the value of your home?

Raised .... ☐1
Lowered......... ☐2 ——► (SKIP TO QUESTION 27c)
No effect....... ☐3 ——► (SKIP TO QUESTION 28) (46)
Not sure .... ☐3 ——► (SKIP TO QUESTION 28)

27b. By approximately what percent has it raised the resale value?

_____________% ——► (SKIP TO QUESTION 28) (47-49)

27c. By approximately what percent has it lowered the resale value?

_____________% (50-52)

28. If you financed your home purchase or passive solar retrofit through a financial institution, do you think that the passive solar aspects of your home had a positive, a negative, or no appreciable effect on your ability to obtain financing?

Positive effect .... ☐1
Negative effect .... ☐2
No appreciable effect .... ☐3 (53)
Don't know .... ☐4
Did not use financial institution .... ☐5

29. Do you consider passive solar to be your primary heating system or an auxiliary heating system, that is, one that supplements another system which provides the majority of your household heating needs?

Passive solar is primary ..... ☐1
Passive solar is auxiliary ... ☐2 (54)
Not sure .... ☐3

30a. Below is a list of factors that may have influenced your decision to have passive solar features in your home. First, please read the entire list of factors. Then rate each factor according to its importance to you by using the scale provided in column (a). For example, if you think the first factor is very improtant, put an "X" in the box under "very". If the factor was only somewhat important to your decision, put an "X" in the box under "somewhat." If the decision was not very important to your decision, but it was something you thought about, put an "X" in the box under "not very". If the factor was something you did not consider in your decision, mark the box under "Did not consider." Complete Question 30a for all three listed factors.

30b. After you have rated each factor's importance to your decision, think about which factors, of the ones you have rated "very" or "somewhat" important, were the <u>three</u> most important factors in your decision to have passive solar features in your home. Indicate which of these factors was the <u>most important</u> in your decision to have passive solar features in your home by placing a "1" in the box in the far right column on the row with that factor. Place a "2" in the box that corresponds to the <u>second most important</u> factor and a "3" in the box that corresponds to the <u>third most important factor</u>.

	30a				30b	
	Importance in Decision				Three Most Important Factors	
Factors	Very	Somewhat	Not Very	Do Not Consider		
National energy conservation	☐1	☐2	☐3	☐4 (55)	☐	(70)
Being close to nature	☐1	☐2	☐3	☐4	☐	
Provide more comfortable environment	☐1	☐2	☐3	☐4	☐	
Have a greenhouse for indoor gardening/food production	☐1	☐2	☐3	☐4	☐	
Increase value of house	☐1	☐2	☐3	☐4	☐	
Protect family against fuel shortages	☐1	☐2	☐3	☐4	☐	
Hobby interest	☐1	☐2	☐3	☐4	☐	
Use renewable energy sources	☐1	☐2	☐3	☐4	☐	
Provide an attractive environment in which to live	☐1	☐2	☐3	☐4	☐	(78)
					79 [0 2] 80 Card 3	
Recovery time for cost of passive solar features (payback period)	☐1	☐2	☐3	☐4	☐	(1-4) (5)
Save on fuel costs	☐1	☐2	☐3	☐4	☐	(6)
Exterior appearance	☐1	☐2	☐3	☐4	☐	(7)
Floor design	☐1	☐2	☐3	☐4	☐	(8)
Luxury of warm rooms without extra cost	☐1	☐2	☐3	☐4	☐	(9)
Provide day lighting	☐1	☐2	☐3	☐4 (69)	☐	(10)

31. Were any of the design or construction costs for your house directly subsidized by a grant or contract from a federal agency or other agency?

Yes .... ☐1
No .... ☐2 (11)

32. You may have been eligible for federal or state tax credits for passive feature costs either as "solar" or "conservation" credits. Did you claim a tax credit?

Yes .... ☐1
No .... ☐2 → (SKIP TO QUESTION 34a) (12)

33. Please indicate below the tax credits that you claimed (including any unused credits carried forward to future years). Fill in all blocks; indicate 0 where applicable.

Item	Federal	State	
Solar	$ ______	$ ______	(13-22)
Energy Conservation	$ ______	$ ______	(23-32)

34a. Which of the following people, if any, showed you calculations of the energy cost savings that you could expect to achieve from your passive solar features?

Person	Provided Calculations	
Builder	☐1	
Architect	☐2	
Engineer	☐3	
Real Estate Agent	☐4	(33)
Did Calculations Myself	☐5	
Other (please list)		
______________	☐6	
______________	☐7	
______________	☐8	
None of the above	☐9	

34b. ANSWER THIS QUESTION ONLY IF IN QUESTION 34A, YOU ANSWERED "DID CALCULATIONS MYSELF." What tool(s) did you use to calculate energy costs savings?

____

____

____

35. Whether or not you have previously calculated energy savings, we would now like to ask you some questions about both estimated and anticipated energy savings. If your use of passive solar does not apply to cooling, enter "0" % in the "Cooling" column. If it does not apply to heating, enter "0"% in the heating column.

	Heating	Cooling	
(a) When the passive solar features of your home were designed, what percentage of your annual heating and cooling needs did you <u>expect</u> them to provide?	____ %	____ %	(34-39)
(b) For the last year, what percentage of your heating and cooling needs do you estimate <u>were supplied</u> by passive solar?	____ %	____ %	(40-45)
(c) Thinking ahead to next year, what percentage of your heating and cooling needs do you <u>anticipate being supplied</u> by the passive solar features of your home?	____ %	____ %	(46-51)

SECTION F: SATISFACTION LEVEL

36. All things considered, how satisfied are you with your passive solar home or retrofit?

Very satisfied .... ☐1 (52)
Somewhat satisfied ...... ☐2
Not at all satisfied .... ☐3

37. What is the greatest source of satisfaction with your passive solar home or retrofit?

____

____

38. What is the greatest source of dissatisfaction?

____

____

39. Below is a list of aspects of your passive solar home. Please indicate below your degree of satisfaction (very, somewhat, or not at all satisfied) with the aspects listed below.

How Well Satisfied

Aspect	Very	Somewhat	Not At all	No Opinion	
Energy Savings	☐1	☐2	☐3	☐4	(53)
Heat distribution	☐1	☐2	☐3	☐4	
Cooling distribution ..	☐1	☐2	☐3	☐4	
Humidity control	☐1	☐2	☐3	☐4	
Exterior design of house	☐1	☐2	☐3	☐4	
Comfort level	☐1	☐2	☐3	☐4	
General maintenance requirements	☐1	☐2	☐3	☐4	
Effort and time required in daily operation	☐1	☐2	☐3	☐4	
Performance of mechanical components	☐1	☐2	☐3	☐4	
Floor plan	☐1	☐2	☐3	☐4	
Interior design	☐1	☐2	☐3	☐4	(63)

40. Please list below all items that you labeled in Question 39 as "Not At All Satisfied" with, and briefly describe your reasons for dissatisfaction:

Item	Reason for Dissatisfaction
________________	________________________
	________________________
________________	________________________
	________________________
________________	________________________
	________________________
________________	________________________
	________________________

41. Was your choice of furnishings, floor coverings, or window treatments affected by the fact that you have a passive solar system?

Yes .... ☐1
No .... ☐2 ➞ (SKIP TO SECTION I) (64)

42. Please briefly describe the ways in which your choices of furnishings, etc. were affected by your passive solar system:

____
____
____
____
____

SECTION G: PROBLEMS AND SOLUTIONS

The four questions in this section ask about problems you may have experienced with the passive solar features of your home, both in the primary living spaces and in any greenhouse, sunspace or other "buffer" spaces. "Primary living space" includes all areas that are maintained within 10° of your home's temperature. While some people have greenhouses or sunspaces that are very much a part of the primary living space, many of them have greater than 10° temperature fluctuations and are "lived in" only some of the time. These spaces have different problems than the primary living space and are dealt with in the fourth question in this section. The first three questions deal with the primary living space only.

43. Have you ever had problems with overheating in your primary living space as a result of the passive solar features of your home?

Yes .... ☐1
No .... ☐2 ➞ (SKIP TO QUESTION 46) (65)

44. If you do have such problems with overheating please answer the following questions in the table below.

a). For each season, is overheating a problem? (If no, answer a. for the next season listed.) (66-78 open) 79 [0][3] 80 Card 4 (1-4 dup)

b). Please list the hours between which the overheating problem occurs. Be sure to indicate whether each time is "A.M." or "P.M.".

c). Write down the average number of days per month in this season when overheating occurs.

d). Please mark the appropriate box below to show whether the rooms which overheat are rooms with Southern exposed glass, other rooms with no Southern glass, or both types of rooms.

e). When your home overheats, how uncomfortable is your household? Please mark the box to show whether it is "very", "somewhat", or "not at all" uncomfortable.

	44a		44b	44c	44d			44e			
Season	Overheating a Problem?		Time in which Overheating Occurs (such as 10 AM - 1 PM)	Average No. of Days per Month it Occurs	Which Rooms Overheat?			When it Overheats, uncomfortable is household?			
	Yes	No			Rooms with south glass	Other rooms	Both types	Very	Some-What	Not At All	
Summer.	☐	☐	[-]	[ ]	☐	☐	☐	☐	☐	☐	(5-15)
Fall...	☐	☐	[-]	[ ]	☐	☐	☐	☐	☐	☐	(16-26)
Winter.	☐	☐	[-]	[ ]	☐	☐	☐	☐	☐	☐	(27-37)
Spring.	☐	☐	[-]	[ ]	☐	☐	☐	☐	☐	☐	(38-48)

45. What actions have you taken to correct your overheating problems? Please describe those actions on the lines below.

____

____

____

____

____

46a. On the next page is a table listing other problems you may have experienced in your <u>primary living space</u> related to the passive solar features of your home. For each problem listed, please mark the box to show if you experienced the problem. If you did experience a problem, complete 46b - 46f for each problem experienced.

46b. Please mark the appropriate box in the table to show whether you felt the problem was "very", "somewhat", or "not very" serious.

46c. For each problem you experienced, mark the box under Yes or No to show whether you took any action towards correcting the problem.

46d. On the line provided, please briefly describe the action taken to correct the problem.

46e. If you had a builder for the passive solar features of your home, make the box under Yes or No to indicate whether the builder took steps to correct the problem.

46f. Finally, for each problem, indicate whether or not the problem has now been corrected <u>to your satisfaction</u>.

46a - 46f (continued) Problems in the Primary Living Space

	46a	46b			46c		46d	46e		46f	
Problem	Ever Had?	How Serious Was It?			Took Action?		Action Taken	Builder Help?		Corrected to your Satisfaction?	
	("X" ALL THAT APPLY) (49-50)	Very	Somewhat	Not Very	Yes	No		Yes	No	Yes	No
Glare	☐1	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (51-54)
Excessive humidity	☐2	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (55-58)
Condensation on Windows	☐3	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (59-62)
Keeping windows or other glass areas clean	☐4	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (63-66)
Stagnant odors	☐5	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (67-70)
Fading of furniture, walls or coverings	☐6	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (71-74)
Lack of privacy	☐7	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (75-78)
Drafts	☐8	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (5-8)
Rooms cool down too fast ...	☐9	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (9-12)
Not warm enough	☐0	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (13-16)
Extreme temperature swings	☐X	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (17-20)
Weatherstripping or Caulking	☐R	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (21-24)
Covering sloped windows	☐-1	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (25-28)
Assured solar access	☐-2	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (29-32)
Zoning restrictions	☐-3	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (33-36)
Building codes	☐-4	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (37-40)
Mechanical/electrical system failures	☐-5	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (41-44)
Other (Please List)											
______	☐-6	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (45-48)
______	☐-7	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (49-52)
______	☐-8	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (53-56)
______	☐-9	☐1	☐2	☐3	☐1	☐2	______	☐1	☐2	☐1	☐2 (57-60)

79 [0] [4] 80
Card 5
(1-4 dup)

47a. Now, for ONLY those problems affecting your primary living space that you said were not corrected to your satisfaction (Question 46f or 46c "no"), please mark box on the table below to show how serious the problem is now.

47b. Mark Yes or No to show whether you plan to take any action in the future.

47c. If you plan to take action, please describe on the line provided the action you plan to take.

Uncorrected Problem in Living Spaces	47a How Serious Now? Very	Somewhat	Not very	47b Do You Plan Further Action? Yes	No	47c Action Planned
Glare	☐1	☐2	☐3(61)	☐1	☐2(62)	____
Excessive humidity.......	☐1	☐2	☐3(63)	☐1	☐2(64)	____
Condensation on windows..	☐1	☐2	☐3(65)	☐1	☐2(66)	____
Keeping windows or other glass clean	☐1	☐2	☐3(67)	☐1	☐2(68)	____
Stagnant odors	☐1	☐2	☐3(69)	☐1	☐2(70)	____
Fading of furniture, walls or coverings	☐1	☐2	☐3(71)	☐1	☐2(72)	____
Lack of privacy	☐1	☐2	☐3(73)	☐1	☐2(74)	____
Drafts	☐1	☐2	☐3(75)	☐1	☐2(76)	____
Rooms cool down too fast.	☐1	☐2	☐3(77)	☐1	☐2(78) 79 0 5 80	____
Not warm enough	☐1	☐2	☐3(5)	☐1	☐2(6) Card 6 (1-4 dup)	____
Extreme temperature swings	☐1	☐2	☐3(7)	☐1	☐2(8)	____
Weatherstripping or caulking	☐1	☐2	☐3(9)	☐1	☐2(10)	____
Covering sloped windows..	☐1	☐2	☐3(11)	☐1	☐2(12)	____
Assured solar access	☐1	☐2	☐3(13)	☐1	☐2(14)	____
Zoning restrictions	☐1	☐2	☐3(15)	☐1	☐2(16)	____
Building codes	☐1	☐2	☐3(17)	☐1	☐2(18)	____
Mechanical/electrical system failures	☐1	☐2	☐3(19)	☐1	☐2(20)	____
Other (Please List)						
____	☐1	☐2	☐3(21)	☐1	☐2(22)	____
____	☐1	☐2	☐3(23)	☐1	☐2(24)	____
____	☐1	☐2	☐3(25)	☐1	☐2(26)	____

48. Do you have a greenhouse, sunspace or other "buffer spaces" (i.e., a space where the temperature goes more than 10 higher or lower than the living space)?

Yes .... ☐1 ➔ Type of space: Greenhouse ...... ☐1
No .... ☐2 ➔ Skip to Section H Sunspace .... ☐2 (28)
Other .... ☐3

49a. Below is a list of problems you may have experienced with your greenhouse, sunspace, or other "buffer spaces". In the first column, mark an "X" in the box next to these problems you have experienced. For each problem you have "X"ed, answer Questions 49b - 49e.

49b. Please indicate by marking the appropriate box how serious you felt the problem was.

49c. For each problem that you have experienced, indicate whether or not you took any action to correct it.

49d. Describe on the provided lines the action that you took.

49e. Indicate whether the problem was corrected to your satisifaction.

Problem ("X" ALL THAT APPLY)	Ever had? (29)	How Serious Was It? Very	Somewhat	Not Very	Took Action Yes	No	Action Taken	Corrected To Your Satisfaction? Yes	No	
Overheating	☐1	☐1	☐2	☐3	☐1	☐2	________	☐1	☐2	(30-32)
Requires too much backup heat..	☐2	☐1	☐2	☐3	☐1	☐2	________	☐1	☐2	(33-35)
Condensation	☐3	☐1	☐2	☐3	☐1	☐2	________	☐1	☐2	(36-38)
Keeping glass clean	☐4	☐1	☐2	☐3	☐1	☐2	________	☐1	☐2	(39-41)
Other:										
________	☐5	☐1	☐2	☐3	☐1	☐2	________	☐1	☐2	(42-44)
________	☐6	☐1	☐2	☐3	☐1	☐2	________	☐1	☐2	(45-47)

SECTION H: GENERAL PASSIVE SOLAR CHARACTERISTICS

50. Are any of the passive solar components in your home covered by a builder's warranty?

Yes .... ☐1
No .... ☐2 ➔ (SKIP TO QUESTION 53) (48)

51. Do you feel that the warranty is adequate?

Yes .... ☐1 ➔ (SKIP TO QUESTION 53)
No .... ☐2 (49)

52. Please describe briefly why you feel that the warranty is not adequate:

____

____

53. Were operating instructions provided for the passive solar features of your home?

Yes .... ☐1
No .... ☐2 ➔ (SKP TO QUESTION 56) (50)

54. Do you feel that the instructions were adequate?

Yes .... ☐1 ⟶ (SKIP TO QUESTION 57) (51)
No .... ☐2

55. Please describe briefly in what ways you feel the instructions were not adequate:

____

____

---------------------------------- (SKIP TO QUESTION 57) ------------------------------

56. Do you feel that some operating instructions would have been useful to you?

Yes .... ☐1 (52)
No .... ☐2

57. Now we would like to ask you some questions about components of your home that may require manual operation. Below is a list of components which you may have and which might require manual operation. Please indicate:

(a) which components you have,
(b) which components you have that require manual operation,
(c) how inconvenient you find any required manual operation, and
(d) are any so inconvenient that you don't operate them as often as you should?

If the answer to (a) or (b) is "NO" for any component, skip to the next component.

	(a)	(b)	(c)			(d)
Component	Have?	Manual?	How Inconvenient?			Too Inconvenient To Operate
			Very	Somewhat	Not at all	
	(53)	(54)				(63)
Shade or other sun-screening devices	☐1	☐1	☐1	☐2	☐3(55)	☐1
Reflector panels	☐2	☐2	☐1	☐2	☐3(56)	☐2
Vents	☐3	☐3	☐1	☐2	☐3(57)	☐3
Movable insulation	☐4	☐4	☐1	☐2	☐3(58)	☐4
Fans	☐5	☐5	☐1	☐2	☐3(59)	☐5
Other (please list)						
____________	☐6	☐6	☐1	☐2	☐3(60)	☐6
____________	☐7	☐7	☐1	☐2	☐3(61)	☐7
____________	☐8	☐8	☐1	☐2	☐3(62)	☐8

SECTION I. PERSONAL INFORMATION. As stated in the Introduction, this information will be kept confidential.

58. How many people live here? ____________ (64-65) How many of those people are over 18 years of age? ____________

59. For each occupant over 18 years of age, please complete the following information.

Person #	Age					Employment Status			Education					Sex		Occupation
	18-20	21-30	31-45	46-65	Over 65	Full	Part	Unemp.	Some H.S. or less	H.S. grad	Some college or trade	College grad	Post-grad. work/degree	M	F	
1	☐1	☐2	☐3	☐4	☐5	☐1	☐2	☐3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	____________ (66-69)
2	☐1	☐2	☐3	☐4	☐5	☐1	☐2	☐3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	____________ (70-73)
3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	☐3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	____________ (74-77)
4	☐1	☐2	☐3	☐4	☐5	☐1	☐2	☐3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	____________ 79 [0 6] 80 (5-8)
5	☐1	☐2	☐3	☐4	☐5	☐1	☐2	☐3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	____________ (9-12)
6	☐1	☐2	☐3	☐4	☐5	☐1	☐2	☐3	☐1	☐2	☐3	☐4	☐5	☐1	☐2	____________ (13-16)

60. Which of the following categories includes your total yearly household income from all sources, before taxes?

Less than $10,000 .... ☐

$10,000 to less than $20,000 .... ☐

$20,000 to less than $30,000 .... ☐ (17)

$30,000 to less than $40,000 .... ☐

$40,000 and over .... ☐

(18-78 open)

79 [0 7] 80

Appendix B:
Audit Form

PERFORMANCE EVALUATION OF

PASSIVE/HYBRID SOLAR HEATING AND COOLING SYSTEMS

CLASS "C" AUDIT FORM

GENERAL

1. Site Code Number: ______________________

2. Auditor Code Number: ______________________

3. Auditor Name: ______________________

4. Date of Audit: __________ month ______ day ______ year

5,6,7 are "Confidential" — OCCUPANTS NAME(S), ADDRESS AND PHONE #

8. (a) Date house or retrofit passive solar system completed and operational:

__________ month __________ year

(b) Date house occupied by present occupants: __________ month ______ year

---

Notes:

9. Name of principal solar designer(if designed by owner, write "owner" and leave address and phone number blank):

____

This person is the: (check as many as apply)

- ◯ architect
- ◯ engineer
- ◯ builder
- ◯ owner
- ◯ other

address ______________________

____

____

phone number: (___)-____________

10. (a)Name of builder (if owner-built, write "owner" and leave address and phone number blank):

____

address: ______________________

____

telephone number:(___) ____________

(b)Are drawings of the house available?

- ◯ yes
- ◯ no

If so, from whom? ______________________

____

Are these drawings attached?

- ◯ yes
- ◯ no

11. Number of occupants at home during: Daytime ____________

Evening and night ____________

ENVIRONMENT

12. (a) ZIP Code: ____________

(b) Site location: ________ miles ____________ of ____________

direction nearest city

Altitude ________ (feet)

12. (continued)

(c) Does the climate vary significantly from the climate of the above city?

yes ◯ no ◯ don't know ◯

If yes, describe variation, at least including temperature variation for degree day adjustment. (If variation is known from some other location, name location and describe variation).

____

____

____

13. Altitude of horizon (to nearest 5^{o} including non-deciduous trees, buildings, etc.)

azimuth:	East 90°	60°	30°	South 0°	-30°	-60°	West -90°
angular altitude							

14. Sketch site plan on the graph paper provided (next page). Note density, type, and height of vegetation or other objects which cast significant shadows on the house. Also include windbreaks. Label approximate distances from house and approximate house dimensions. Roughly center the house on the graph paper and place an "X" where you stood when you noted the horizon altitudes in number 13. Label all objects in the drawing and designate all vegetation deciduous or evergreen.

Draw an arrow on the sketch indicating North - label this true North or magnetic North.

Take a photograph standing at the place marked "X" on the sketch, looking out perpendicular from the aperture.

15. Solar access of the site:

- ◯ High
- ◯ Slightly obstructed
- ◯ Restricted

Describe the features that make this a particularly good or bad site for solar access:

____

____

____

____

____

16. The surface of the ground for the first 20 feet to the south of the solar aperture is:

LAST WINTER:

- ◯ ice, snow or other reflective surface
- ◯ open water
- ◯ grass, dirt or other colored surface

SUMMER:

- ◯ white or other reflective surface
- ◯ open water
- ◯ grass, dirt or colored surface

Circle the months during which this surface was snow-covered last year:

J A S O N D J F M A M J None

17. Exposure to wind during the summer is:

- ◯ high
- ◯ medium
- ◯ low

during the winter is:

- ◯ high
- ◯ medium
- ◯ low

Describe site features contributing to winter wind sheltering and summer breeze access:

____

____

____

____

____

18. Is the site subject to fog, significant pollution, or other factors which affect availability of solar radiation?

◯ yes
◯ no

If yes, describe condition, including frequency and severity:

____

____

____

____

____

THERMAL DESCRIPTION OF BUILDING (NON-SOLAR)

19. Type of building:

◯ single-family detached
◯ single-family attached (row): number of units in row:__________
◯ multi-family: number of units in building______________________
◯ other: describe____

If other than single-family detached, indicate shared walls, ceilings and floors. Also describe location of unit in building (e.g., "upstairs unit on west end, shares floor and east wall with other units"):

____

____

20. General type of construction:

◯ wood frame (includes post and beam)
◯ wood frame with masonry exterior
◯ masonry with exterior insulation
◯ masonry with interior insulation
◯ other, describe____

21. Building has:

	square feet
◯ heated crawlspace	__________
◯ unheated crawlspace	__________
◯ basement	__________
◯ slab-on-grade	__________
◯ other (describe)	__________

You may check more than one. If more than one is checked, indicate approximate number of square feet of each.

22. Size and control temperatures of heated and cooled living spaces: (Include sunspaces, greenhouses, basements and other spaces as "living spaces" or if they are usually kept within 10 degrees F of the rest of the house)

Code	Type of Space
1	first floor
2	second floor
3	third floor
4	fourth floor
5	basement - heated
6	greenhouse with plants
7	solarium (no plants)
8	combination greenhouse/solarium
9	other (describe) :

____

____

Living Space Code Number (see above)	Floor Area (ft^2)	Average Indoor Temperature Maintained			Maximum Indoor Temp Maintained (for cooling)
		Day (°F)	Hours/Day at Day Temp.	Night (°F)	

Temperature set-backs are:

○ automatic
or
○ manual

○ No temperature set-back

23. Are there other significant factors which will affect the overall heat loss?

○ Yes
○ No

If yes, describe below. These may include periods of time during which occupants are away and thermostats are lowered, shutting off certain rooms in the winter, or zones which regularly experience temperatures above the thermostat set point. For higher or lower temperature ranges, describe the temperatures experienced, during which months, and at what times of day.

____

____

____

23. (continued)

Also identify any unusual aspects of occupancy, such as: home used for day care center or nursery; business carried on at home (such as laundry service or shop); or any other atypical heat-producing activity.

____

____

____

24. Heat Loss from living space
Do NOT include here: shared surfaces in multi-family units; passive solar apertures, or sunspaces unless they are part of the living space (that is, unless they are kept within 10 degrees of the living space). Refer to typical U values in Chart A of the Instructions.

(a) Non-south glazing

	Description	Gross Area (ft^2)	U Value Day	U Value Night	Description and Schedule of use of night insulation	Weighted Average U-Value	UA Btu/hr°F
East							
West							
North							

Total Non-South Glazing UA: ________

Notes: (1) "Gross Area" is "finished opening" area, that is, the area of glass plus sash.
(2) "U Value - Night" is the U value of the night insulation plus glazing
(3) See table in instructions for U values of various glazing configurations

24. (continued)

Wall Area Workspace

	Wall Width	X	Wall Height	=	Gross Wall Area	-	Window plus Door Area	=	Net Wall Area
N									
E									
W									
S									

TOTAL AREA	

(b) UA Calculation for Walls, Doors and Ceilings. See Chart A in instructions for typical U values. Do not include surfaces behind solar collection areas

	Description	Total Area(ft^2)	U Value	UA (Btu/hr.F°)
Walls				
Doors (less any window area)				
Ceiling				

Total Wall, Door and Ceiling UA	

24. (continued)

(c) Heat Loss Through Floors and Basement Walls - Fill in either or both of the two tables below, as appropriate:

	Description		Heat Loss Factor from Chart	UA (Btu/hr °F)
Above-Grade Wall (Chart A)		Area (ft^2)		
Below-Grade Wall (Chart B)		Perimeter (ft)		
Floor (Chart C)	full perimeter insulation only	Perimeter (ft)		
	all other floors except vented crawl space	Area (ft^2)		
Floor (Chart A)	floors over vented crawl spaces only	Area (ft^2)		
			Total Estimated UA for Floors and Basement Walls	

(d) Infiltration - See Table D in instructions for classification of infiltration control levels and estimated rates to enter in table below. Describe any major departures from characteristics described in Chart D:

____

____

____

	Air Change Rate (changes/hr) from Chart D	Volume of Heated Space (ft^3)	Conversion Constant (Btu/°F ft^3)	Infiltration Heat Loss Rate (Btu/ hr °F)
House	( )	X ( )	X (.018)	=
Heated basement	( )	X ( )	X (.018)	=
			Total infiltration loss rate	

24. (continued)

(e) Total Heat Losses from Building, Excluding Solar Aperture

Total Non-South Glazing Loss Rate	
Total Wall , Door and Ceiling Loss Rate	
Total Floor and Basement Wall Loss Rate	
Total Infiltration Loss Rate	
Total Non-Aperture Loss Rate (Btu/ hr· °F)	

(f) Exterior color of house:

	light	medium	dark
walls:	○	○	○
roof:	○	○	○

(g) Is there an air-to-air heat exchanger? If so, describe: ____________________

○ yes ____________________

○ no ____________________

(h) Area of vents for roof insulation: __________ ft^2

<u>OR</u>

If ventilation is forced, check this circle and note input power rating and output CFM in question number 25.

○ forced attic ventilation

AUXILIARY ENERGY EQUIPMENT AND INTERNAL GAINS

25. (a) The base case assumption is that the house has typical numbers and types of appliances: one dryer, one washer, one oven, one range, one domestic hot water heater, and one combination refrigertor/freezer. It also assumes they are used typically.

Yes	No	
○	○	Do appliances vary significantly from this list?
○	○	Does their use vary significantly from typical use?

If either question is answered yes, explain atypical appliances and usage:

____

____

____

25. (continued)

(b) The table below requests specific information on appliances:

Appliance	Yes	No	Energy Source			
			Electricity	Gas	Oil	Wood
Clothes dryer						
Clothes washer						
Oven						
Range						
DHW heater						
Refrigerator/freezer						

(c) If there is a clothes dryer, indicate location and winter operational mode:

Location		Mode of operation			
Heated space	Unheated space	Intake air from:		Exhaust vented to:	
		Inside	Outside	Inside	Outside

AUXILIARY ENERGY EQUIPMENT

26. (a) For auxiliary energy equipment code numbers, see Chart E of Instructions. For equipment not listed, use code number 29 and describe in space provided below. Use additional numbers (30,etc.) as needed for other unlisted equipment. Add sheets as needed for other unlisted equipment.

Equipment Code No.	Description of Equipment, Including Input and Output Ratings	Use Pattern of Equipment, Including Control Method	Comments, Including Area Serviced (if not whole house) and Description of Supplementary Conservation Features

26. (continued)

(b) If there is an active solar space heating system, describe below:

Manufacturer and model of system and/or collector:________________

____

Does system function as specified by manufacturer ?

yes ○ no ○ don't know ○

If "no", explain:____

____

____

Type of system: Liquid _________ Air ________

Thermal storage system (size and contents):______________________

____

Characteristics of system:

Collector area (ft^2):______________________

Number of glazing layers:__________________

$F_R \tau \alpha$ (if known):___________________________

$F_R U_L$ (if known):___________________________

Collector slope (90^o = vertical):____________

Azimuth (0^o = South):______________________

(c) If there is an active solar DHW system, describe below:

Manufacturer and model of system and/or collectors:________________

____

Does system function as specified by manufacturer?

yes ○ no ○ don't know ○

If "no", explain:____

____

____

26. (continued)

What is back-up system and how is it connected to solar DHW system?

____

____

Characteristics of system:

Collector area (ft^2): ____________

Number of glazing layers: ____________

$F_R \tau \alpha$ (if known): ____________

$F_R U_L$ (if known): ____________

Storage capacity (gallons): ____________

Collector slope (90° = vertical): ____________

Azimuth (0° = South): ____________

27. Additional Domestic Hot Water information

(a) DHW heater location and type:

yes	no	
○	○	In heated space?

If "yes", indicate type:

○ standard electrical model

○ energy-conserving electrical model

○ standard oil or gas model

○ energy-conserving oil or gas model

(b) Tank size: ____________ gallons

(c) Thermostat setting: ____________

	yes	no	
(d)	○	○	Are low-flow faucets and shower-heads used?
(e)	○	○	Are other conservation measures used?

27. (continued)

(f) Describe insulation thickness on hot water tank and any other conservation features, such as pipe insulation, flue dampers, timers, etc.

____

____

____

____

(g) Estimated number of gallons of hot water used per week:

			gals./wk
Showers per week......................		x 15 gals. =	
Baths per week.......................		x 30 gals. =	
Laundry -loads on "hot" wash per week		x 28 gals. =	
-loads on "warm" wash per wk.		x 16 gals. =	
Dishwasher loads per week............		x 20 gals. =	
Hand dishwashing (times/day x 7)......		x 5 gals. =	
		TOTAL........	
Water conserving devices or practices? (If yes, subtract 15% of TOTAL)			-
		CORRECTED TOTAL........	

28. Additional wood-stove/wood-furnace/wood-boiler/fireplace information

(a) Describe the wood burning equipment, including if the unit is air-tight and other notable features. For fireplaces, describe any equipment used to improve efficiency.

____

____

____

____

28. (continued)

(b) Wood burned is primarily:

- ◯ hardwood
- ◯ softwood
- ◯ half and half

(c) wood burned is primarily:

- ◯ seasoned
- ◯ green

(d) Describe the general operating method and schedule of use of the wood burner(s), including at least the number of hours burned per day, number of fuelings per day, the number of days used per heating season, and whether the damper is closed when the unit is not used.

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PASSIVE / HYBRID SYSTEMS

29. On the following pages, give a brief description and draw a schematic sketch of each passive heating and cooling system in the house. Identify each system with a letter (A - E) corresponding to the designation above question 30. Identify important elements, indicate air flows, and identify any features which may affect performance. Also sketch a floor plan identifying passive systems and storage elements, including approximate dimensions.

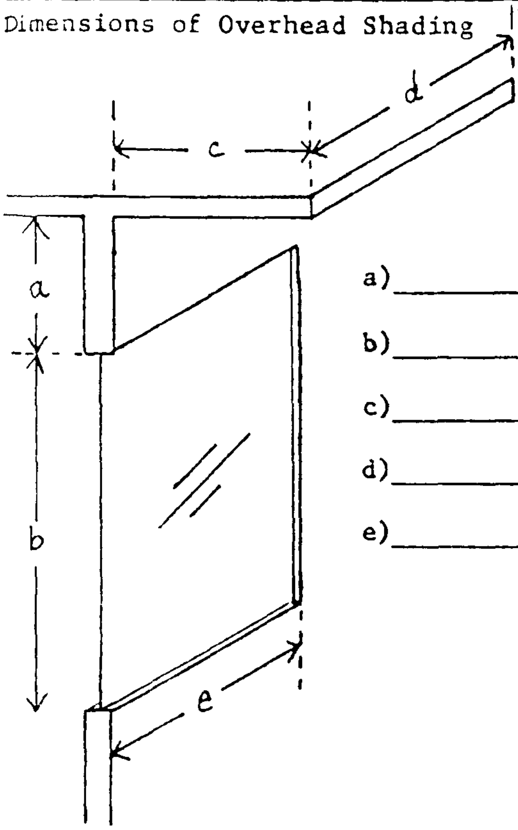
	A Dominant Heating System	B Dominant Cooling System	C Other System	D Other System	E Other System
30. System Code No. (see Instructions Charts F,G for codes. For cooling systems, skip questions 31-40.)					
31. Net clear aperture area (ft^2)					
Gross aperture area (ft^2) (rough opening)					
32. Azimuth (degrees from south)					
33. Slope (deg. from horizontal)					
34. No. of layers of glazing					
35. Glazing material: outer layer					
middle layer					
inner layer					
36. Space between layers					
37. Is there a reflector? (yes or no) If yes, describe in no. 29.					
38. Is there moveable insulation? (yes or no) If yes, give ft^2 covered and describe in no. 46.					
39. R - Value of night insulation					

	A Dominant Heating System	B Dominant Cooling System	C Other System	D Other System	E Other System
40. Is there shading of aperture from above? If so, describe on Shading Worksheet — Fixed	○	○	○	○	○
Moveable	○	○	○	○	○
None	○	○	○	○	○
41. Is there shading of the aperture from the side? If yes, describe on Shading Worksheet. — Yes	○	○	○	○	○
No	○	○	○	○	○
42. Operating energy of fans or pumps: a) Input power rating (specify units)					
b) Number of months in use					
c) Estimated hours per day					
43. Thermal Mass - Primary: a) Configuration Code (see Chart H in Instructions for code)					
b) Thickness (in.)					
c) Area (ft^2)					
d) Volume (specify units)					
e) Material and type (such as "high density concrete")					

	A Dominant Heating System	B Dominant Cooling System	C Other System	D Other System	E Other System
44. Thermal Mass - Other a) Configuration Code					
b) Thickness (in.)					
c) Area (ft^2)					
d) Volume (specify units)					
e) Material					
45. Thermal Mass - Other a) Configuration Code					
b) Thickness (in.)					
c) Area (ft^2)					
d) Volume (specify units)					
e) Material					

SHADING WORKSHEET - System Shaded__________________(A - E)

Dimensions of Overhead Shading



a)______________(ft.)

b)______________(ft.)

c)______________(ft.)

d)______________(ft.)

e)______________(ft.)

j) If shading device is moveable, describe schedule of use.

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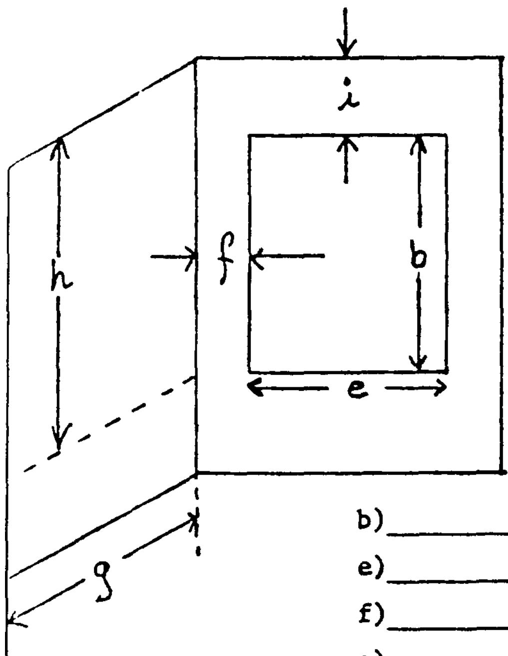
Dimensions of Side Shading



b)______________(ft.)

e)______________(ft.)

f)______________(ft.)

g)______________(ft.)

h)______________(ft.)

i)______________(ft.)

k) If shading system is not adequately described by these two diagrams, sketch here with dimensions.

46. Describe night insulation on any solar aperture (including type, thickness, edge seals, and brand name) and its use schedule. Operation of the night insulation is:

- ○ manual
- ○ automatic

47. Assess each passive system for its good and bad features and physical condition. (Identify each system by letters A - E as designated above question 30.)

48. Comment on any unusual performance of systems noted during the audit. Also comment on any factors which may cause the performance of the house to change as the house is further used and on any factors which may have caused such a change in the past. This would include such factors as an initially wet storage system, changes in occupancy, changes in equipment (such as fans or night insulation) or changes in operating procedure.

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49. Present auxiliary energy suppliers:

Electricity	Gas
Name __________	__________
Address __________	__________
__________	__________
Phone ( ) __________	( ) __________
Oil	**Other** (specify)______
Name __________	__________
Address __________	__________
__________	__________
__________	__________
Phone ( ) __________	( ) __________

Wood Supplier

○ self

○ other

50. Present Energy Use: For ALL forms of energy used in the house, record usage from copies of bills during the interview and from bills obtained from the supplier where not available from the occupant. Include address and phone of supplier if different from present supplier.
Use additional sheets if necessary.

Type	Supplier	Use Period (Dates)	Quantity of Energy Used (specify units)

Appendix C:
Instructions to Auditors

Instructions to Auditors

General Instructions

1. Use pencil--Number 2 or darker--for all answers and sketches. (Blue and colored inks and lighter pencils will not copy well.)

2. Answer ALL questions. Write N/A for "not applicable" if that is the case.

3. Use margins of the pages and extra sheets to explain anything that doesn't fit in the boxes or spaces provided. Identify answers that are continued elsewhere with a "*" and note where that additional information is written. If on the same page, draw an arrow. If elsewhere, identify the note with the number of the question.

4. Do not write on back of pages. Remember these must be xeroxed, so if you refer to attached sketches, be sure they can be xeroxed.

5. Items marked with a "#" are to be filled out by analyst, not auditor.

Specific Instructions by Question Number for Audit Form

1. The first two letters indicate the state; the next two digits indicate the order surveyed (for example, VT01 is the first Vermont site surveyed). Do not assign a site number until you are going to visit the site.

2. Auditor code:
   a) a letter indicating the base of the auditor: N = NESEC
      M = MASEC
      S = SSEC
      W = WSUN

   b) the number assigned to the auditor by the contracting RSEC
      Example: NESEC's first auditor is

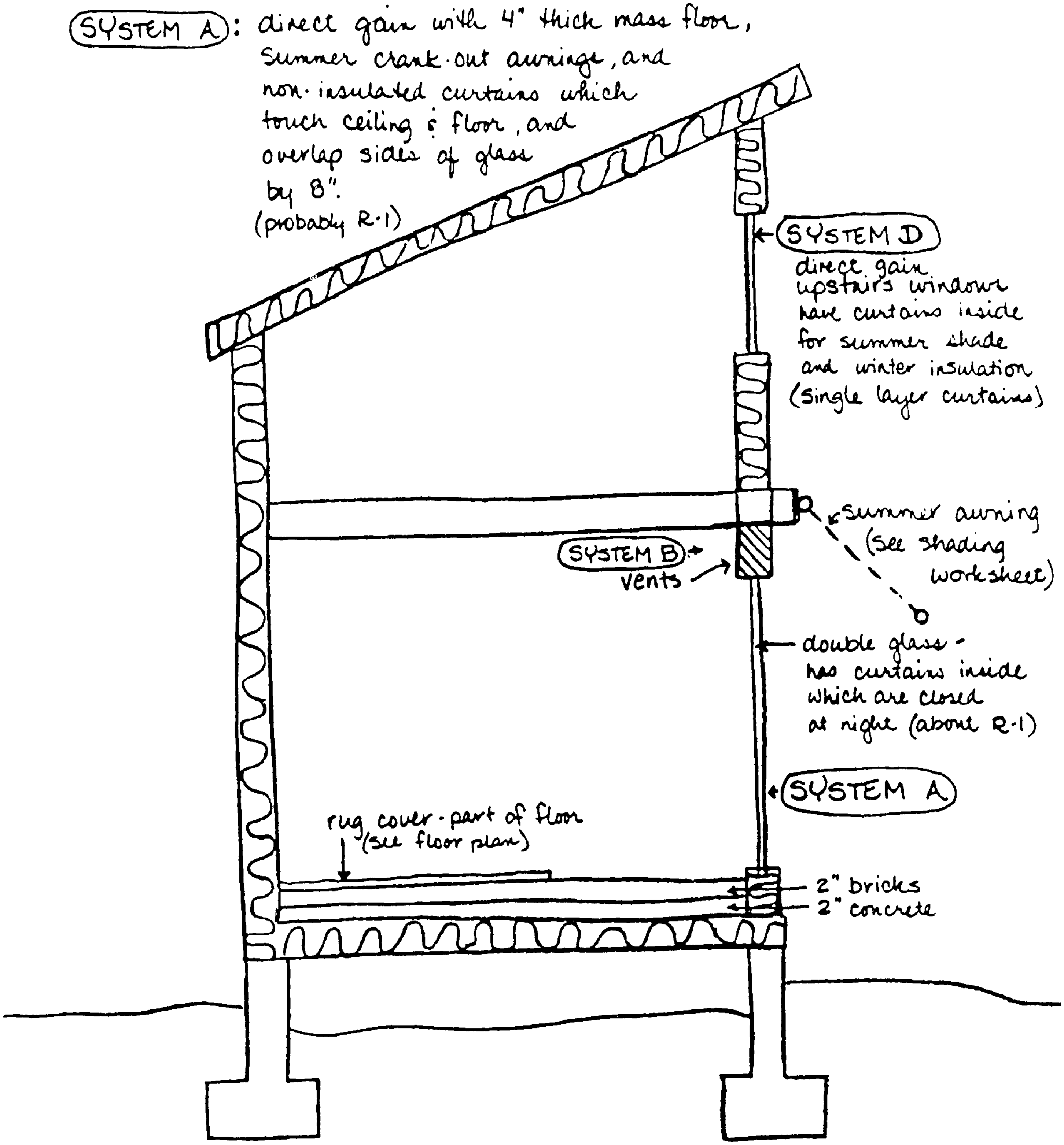
6. If the owner has an extra set of drawings of the house, attach to the questionnaire.

7. This is to help establish weather conditions for use in analyzing heat loss for the houses. The distance is direct, i.e., "as the crow flies." High accuracy is not critical.

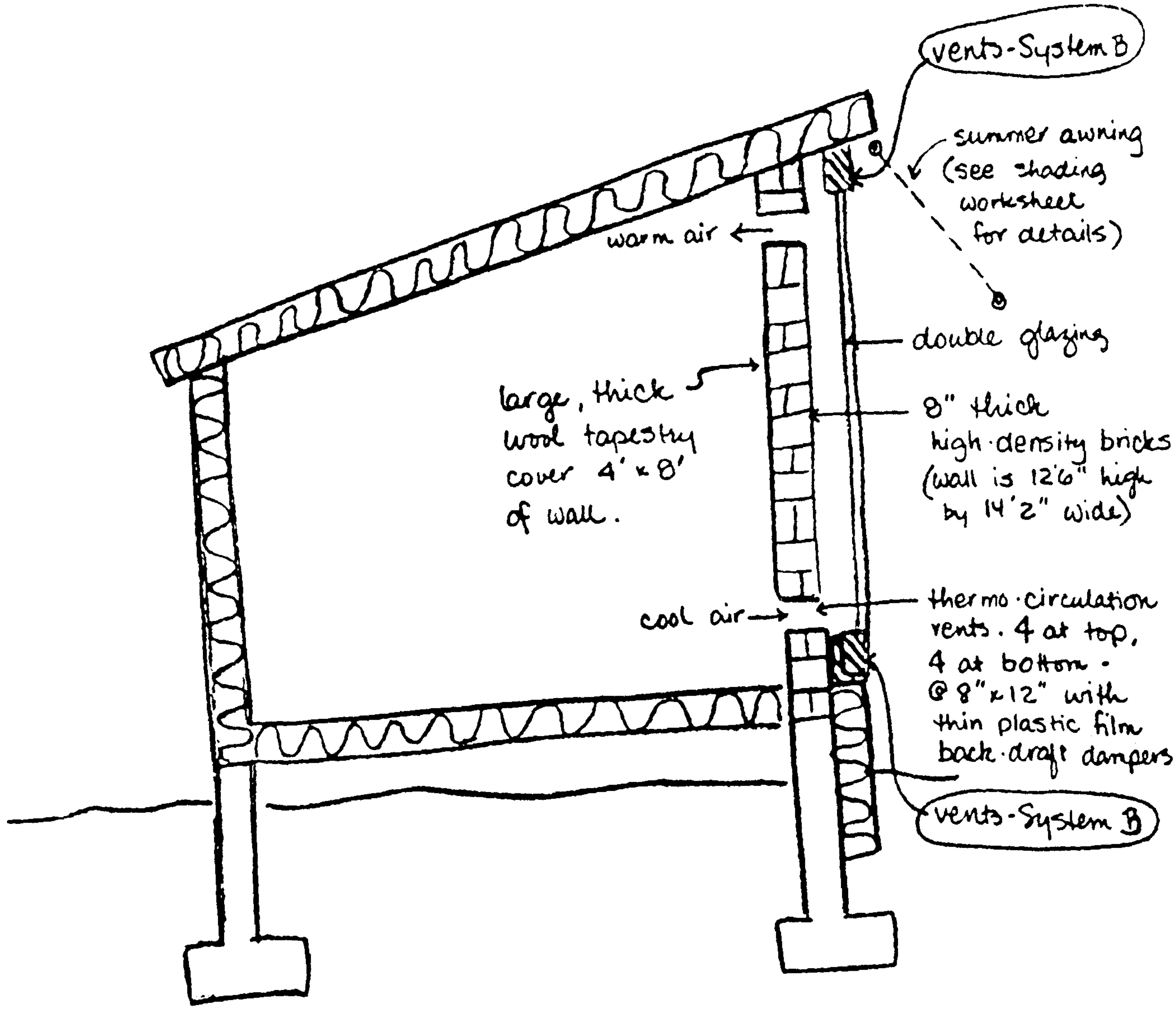
8. High--no obstructions to sun
   Slightly obstructed--some shadows on aperture during a winter day
   Restricted--shaded for at least two hours during sunny winter day

   Describe such features as mountains, trees, adjacent buildings, or other obstructive topographical features.
      Example: "barn shades aperture 10 A.M. in winter"
   Also note if access is great.
      Example: "no obstruction to sun; flat open field for 3 miles to south."

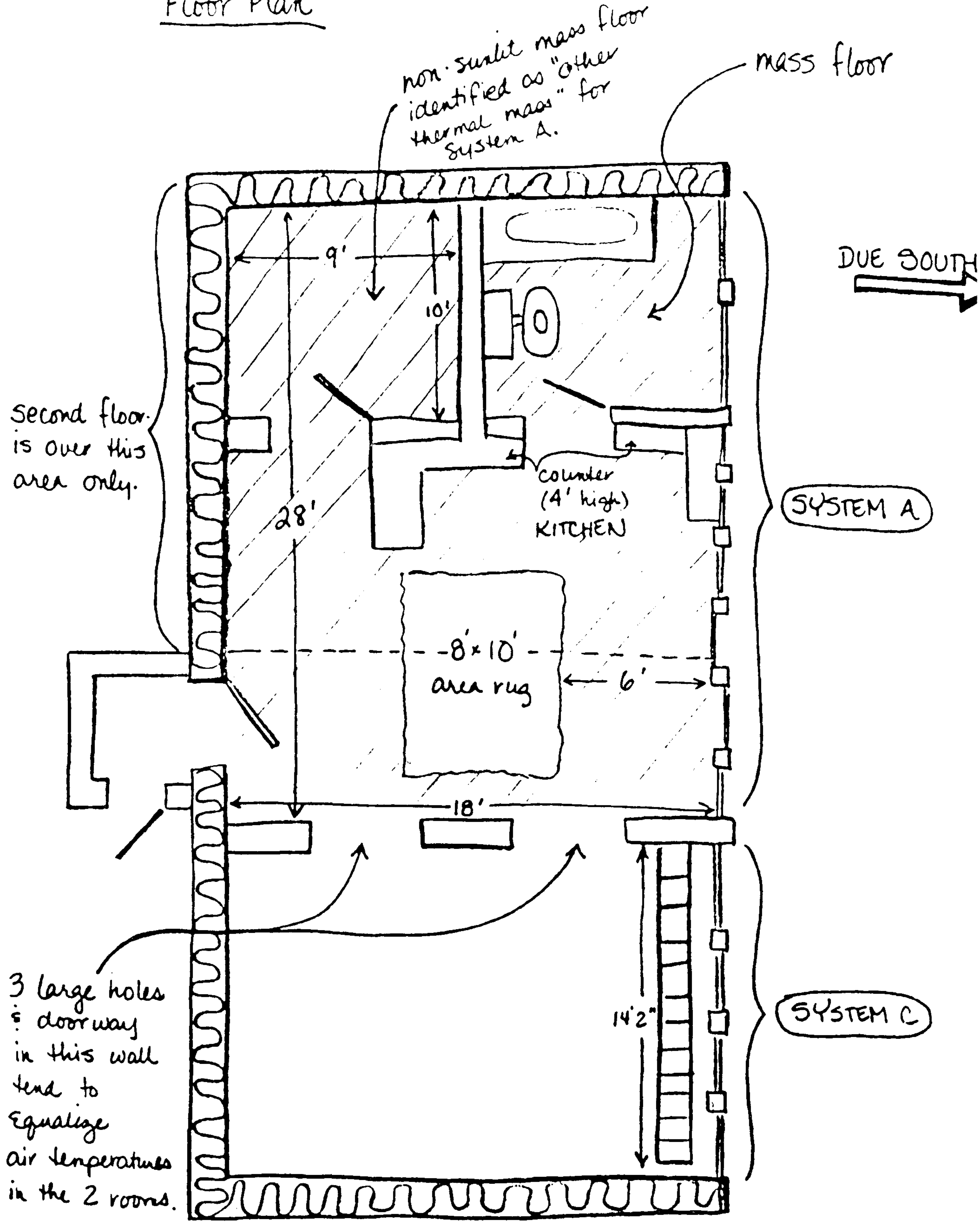
9. This is one of the key questions of the audit. Clearly labeled drawings are essential. The drawings need not be to scale, but critical dimensions should be identified.



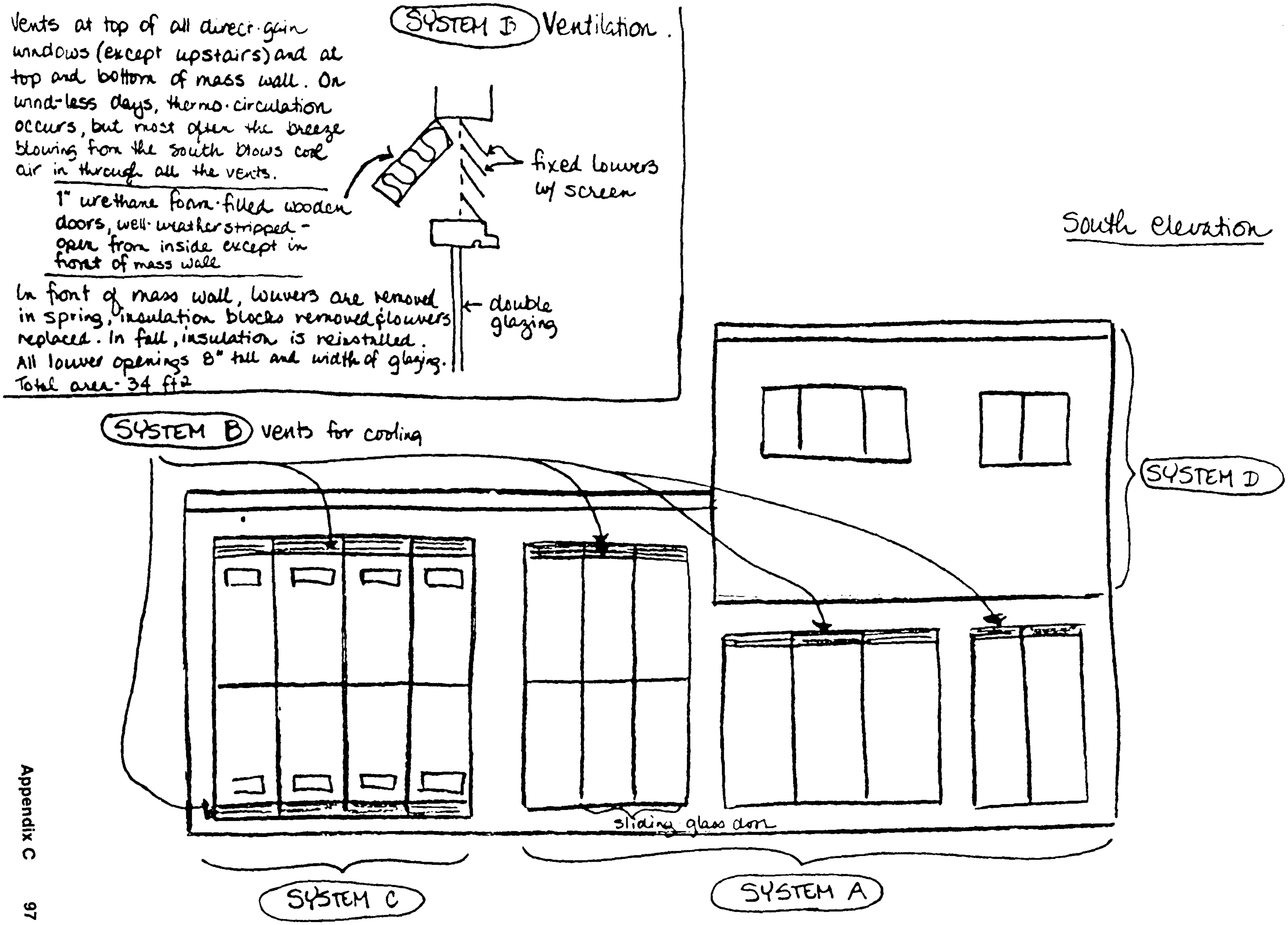
SYSTEM C: Mass wall with thermo·circulation vents, with shading and venting (System B) for summer.



Floor Plan



non-sunlit mass floor identified as "other thermal mass" for System A.
mass floor
DUE SOUTH
9'
10'
28'
second floor is over this area only.
counter (4' high)
KITCHEN
SYSTEM A
8'×10' area rug
6'
18'
14'2"
SYSTEM C
3 large holes & doorway in this wall tend to equalize air temperatures in the 2 rooms.


SYSTEM E Ventilation.
Vents at top of all direct-gain windows (except upstairs) and at top and bottom of mass wall. On wind-less days, thermo-circulation occurs, but most often the breeze blowing from the south blows cool air in through all the vents.
1" urethane foam-filled wooden doors, well-weatherstripped - open from inside except in front of mass wall
fixed louvers w/ screen
double glazing
In front of mass wall, louvers are removed in spring, insulation blocks removed & louvers replaced. In fall, insulation is reinstalled.
All louver openings 8" tall and width of glazing.
Total area - 34 ft2
South elevation
SYSTEM B vents for cooling
SYSTEM D
sliding glass door
SYSTEM C
SYSTEM A

10. See code Charts F and G. Choose the system that most closely matches the one you are auditing. If other than those listed, assign a subsequent code number.

11. a) "Net clear aperture" is the actual clear glazing through which sunlight passes. Excludes mullions, trim, etc.

12. Azimuth is the number of degrees east or west from true south that the glazing faces. Correct your compass reading to determine the true bearing, not magnetic bearing, using the map in Chart I of the Instructions. A typical entry would be "15° west" meaning the aperture faces 15° west of true south.

13. Slope refers to the angle of the glazing aperture. For example, southfacing vertical glass is 90° from horizontal, so the entry would be 90°."

14. One, two, three, or more.

15. Identify materials with generic names or brand names, such as ".040 Kalwall" or 3/16 tempered plate patio-door glass" or ".002 teflon." If more than three, add others at bottom of page and identify these as "other middle layers."

16. Space between layers. This is an estimate based on looking at the glazing, unless you can get this information from the builder or architect, or unless the occupant happens to know.

17. If there is a reflector, be sure it appears in the description and sketches in number 29.

18. If the night insulation covers the whole aperture, give the gross aperture area in 31b.

19. Self explanatory.

20. Mark one of the three circles for each heating and cooling system, if fixed or movable shading is used.

21. (deleted)

22. a) Be sure to specify watts, horsepower, kilowatts, etc. Take this from the plate on the motor. If the motor plate is not easily accessible, obtain ratings from plans, builder, etc., or estimate--"large, small."

    b), c) Self explanatory

23-25. a) Choose one from the configurations a) - h) of Chart H for primary and up to two other thermal masses for each system. Do not include sheet rock unless it is the only mass that applies to the system or unless it is a significant portion of the mass of the system. If more than three thermal mass types are used for one system, use the margin below number 23.

b), c) Self explanatory

d) When calculating volume of masonry materials, be sure to convert inches to feet before multiplying. For water storage, specify ft^3 or gallons, whichever is easier to measure.

e) Describe the material as fully as possible, e.g., "high density, dark brown paving bricks," "pumice aggregate solid concrete block," "water with rust inhibitor," etc.

28. Check whether operation is automatic or manual. Describe the night insulation well enough to be able to estimate its R-value. Enter this estimate in number 38 (not including R-value of window). Include material, thickness, method of movement, method of sealing edges, and brand names where commercial units are used. If at all possible, place the insulation in its closed position for a moment (or have the occupant do this) and note how tightly it closes. Also describe how often and when the night insulation is used. For example: "used 4 out of 5 nights from September-March," "only used on cold nights, this was probably 1/2 of all the nights from November-February," or "only used when backup is required--about 1/2 of all the nights--whenever the day was cloudy."

29. Identify each heating and cooling system with its letter (A-E) and describe what seems to you and to the occupant to be good and bad features of each system. These features might include such comments as: "(A) - direct gain area is too bright and too hot during early fall, but wonderful in midwinter. The mass wall area (C) is very comfortable in the evening all year." "The crank-out awnings are very easy to use (A and C)." "The vents (B) are easy to use, but they leak air." "The upstairs (D) tends to be too hot on sunny winter days unless the window is open." Also, assess the physical condition of each system. You should note such things as peeling of caulking or paint, disheveled weatherstripping, dirty glazing, etc., or simply note "good conditions." Ask the occupant if condensation appears on the windows. If so, note on which windows and how often. Check sills to see if there is evidence of water sitting on the sills or if water has damaged sills.

30. This information will help explain changes in fuel use patterns. Some examples of answers might include: "Night insulation added to all windows 9/10/78." "For January 10-February 20/78, no one used the house and the thermostat was left at 40°." "On January 20, 1979, the blower in the heat storage failed and was replaced with the current one. The old one was 1/2 hp, 500 cfm at 3/4 in. H_2O." "Rained on the rock bin before it was covered. There might have been 6 in. of water in the bottom. There is no drain in the rock storage." "Night-charging of storage with electric heat was done from 9/1 to 11/12/79. This practice has been stopped." "On January 15, three children moved in. One was only 6 months old, and so the thermostat was set at 70° (up from a previous 65°) until June."

31. If unit shares a wall, etc., with a partially heated storage space or entry way, describe that here, indicating temperatures maintained on other side of wall, ceiling, or floor.

33. (deleted)

34. Use code numbers to fill in the chart. For thermostated systems, the average indoor temperatures will usually be the thermostat setpoint. If the thermostat setpoint is the same night and day, put the same temperature in both day and night columns (don't leave blank columns in rows that are filled out), and put "24" under "Hours at Day Temp."

35. This will be of help in explaining abnormally high or low fuel consumption. This differs from question 30 in that here we are looking for regularly occurring periods of overheating, lowered thermostats, decreases in size of the heated space, etc. (Number 30 is aimed at identifying changes in equipment, occupants, etc.) Be sure to describe temperature excursions above setpoint, how low the thermostat is set when the occupants leave the house and when they are gone, what rooms are closed off, when they are closed off, and the number of square feet of closed-off floor area, etc.

36. The auditor will actually estimate the heat loss for the building. This gives the opportunity to understand the building better and a rough check on the calculations.

a) and b) "Description" should include number of layers, type of glazing, and types of window (fixed, casement, double hung, etc.) The spacing between layers need not be listed unless it is different from those in the Heat Transfer Coefficient chart. Skylights should be categorized as either solar apertures (if they transmit direct solar radiation for at least 3 hours per day in winter) or as glazing with the appropriate orientation. Windows in doors and sliding glass doors should be counted as glazed area.

Use the U-values specified for the different glazing combinations in Chart A. Interpolate to determine U-values for intermediate cases, and use a value of 0.50 Btu/h °F ft^2 for double glazings spaced wider than 1 in. Night U-values are for glazing plus night insulation. If no night insulation, list same value as day U-value. Describe briefly the schedule of use of night insulation; for example, "used 6 p.m. to 8 a.m. 4 out of 5 nights, October through February" or "left in place from September 30 to March 1."

Calculate the "weighted average U-value" as follows:

e.g. *For R-4 night insulation used 16 hours per day for the whole heating season, on a single-glazed window with storm:

$$\frac{(.17 \times 16) + (.50 \times 8)}{24} = .28 \text{ weighted average}$$

e.g. *For R-4 used 24 hours per day for a period representing 70% of the degree days, the weighted average is:

$$(.17 \times 16) + (.50 \times .30) = .27$$

e.g. *For R-4 used 16 hours per day for a period representing 70% of the degree days, the weighted average is:

$$\frac{(.17 \times 16) + (.50 \times 8)}{24} (.70) + (.50 \times .30) = .35$$

c) Describe briefly the construction of each item. Door areas should be calculated excluding their glazed area. Wall areas are exterior dimensions. Use the wall area workspace to determine the total wall area. Ceiling areas are the same as floor areas for rooms with horizontal ceilings, but are greater than this in rooms with cathedral ceilings. U-values are taken from Chart A.

d) Fill in the tables as appropriate. For houses with combinations of basements, crawl spaces, etc., complete as many sections of the table(s) as necessary. Treat any above-grade basement or heated crawl space wall as a normal wall section and use Chart A to determine the U-value. For below-grade walls, use Chart B to find the heat loss factors. For basement floors and floor slabs, use Chart C to determine the heat loss factors; for insulated floors over vented crawl space, use Chart A.

e) Determine the air change rate from Chart D. Describe any major departure from the levels outlined and interpolate as necessary. (air change rate) × (volume) × (0.018 Btu/ft^3 °F) = UA (Btu/h °F)

Note: specific heat × assumed density of air = 0.018 Btu/ft^3 °F.

f) Add up all the loss rates to determine the total (nonsolar aperture) loss rate. If this number is not between 300 and 700 Btu/h °F and the house is not unusually small and tight or large and leaky, check your figures for large errors.

g) Self explanatory

h) If yes, describe make and model, air flow rate, heat exchange area and efficiency, if known, how often it is used, and how it is controlled (timer, humidistat, etc.)

38. List fuel bills for the past year (including the last heating season). If more than one year is available, list only annual totals for previous years, if easily obtained. This will usually mean sitting down with the occupants' pile of old bills, sorting them out, and listing the information. Missing information will mean a call or letter to the fuel supplier. Be sure the fuel-bill release form (included) is filled out so you can obtain copies of the bills. The auditor is responsible for obtaining the fuel-use records. A typical entry would be:

Fuel	Supplier	Fuel Use Period	Quantity
Electricity	Central Vermont Public Service	12/1/79 - 2/4/80	245 kWh

or

Fuel	Supplier	Fuel Use Period	Quantity
Fuel oil	Fred Lewis Oil, Co.	12/1/79 - 3/8/80	125 gallons

39. a) "Freezer" means separate freezer, not one in combination with the refrigerator. It is assumed that internally vented dryers are externally vented in the summer.

b) Self explanatory

c) Examples of atypical appliances might include workshop electrical tools used consistently for several hours per day, electric pottery kilns, etc. Specify appliance rating and normal usage pattern. Examples of atypical appliances might include more than one load of laundry per day or doing quantities of home baking for sale. Entries for these cases might look like: "large woodworking tools (radial armsaw--2000 watts, drill press--1500 watts) used average of 4 hours per day, Monday to Friday;" "electric pottery kiln--5000 watts runs 8 hours per week;" and "average of three loads of laundry per day, washed in hot water;" and "electric oven runs about 4 hours per day, every other day."

40. List all auxiliary equipment, including space heating devices, humidifiers, and dehumidifiers. Don't forget pumps and blowers on central heating systems. These are listed as a separate piece of equipment.

Take the code numbers from Chart E.
-Briefly describe the unit such as "50,000 Btu input gas-fired hydronic system. Rated at 78% peak efficiency."
-List how and when used, such as "controlled by thermostat. Generally runs during early a.m. hours after cloudy days."
-Under "comments", describe what part of the house the particular equipment services, unless it is the whole house, such as "heats all but bathroom."
-Also describe, under "comments," conservation features on the equipment, such as "Special high efficiency burner plus flue damper, hot water lines all insulated with 1 in. urethane, electronic ignition."
-Use number 29 for a piece of equipment that is not listed in the code. Use additional numbers if necessary. Append a sheet if more space is required.

41. a) and b) Self explanatory

c) Enter actual degrees F, if the thermostat is calibrated in degrees, or "high," "medium," or "low" if that is how the thermostat is marked. Note that many electric heaters have upper and lower thermostats. In this case, average the two settings.

d), e), f), g), h), and i) Self explanatory

42. Include any features of the wood-burning equipment that affect its efficiency. Critical variables in wood-burning efficiency include stove air tightness and other efficiency boosting features (28-a), type of wood 28-b), moisture content (28-c), and the quantity of wood or coal (28-d). Long, slow-burning fires tend to burn at low efficiency, whereas fast-burning fires tend to burn at higher efficiencies. Wood that has been seasoned less than 6 months over the summer is considered green.

Appendix D:
Reference Charts

Chart A: Heat Transfer Coefficients for Typical Construction

Wall, Ceiling and Floor Sections

Type	Variations	h ft^2 °F/Btu R	Btu/h ft^2 °F U
Frame wall	2 × 4 no insulation	3.9	.257
	2 × 4 3 1/2" fiberglass	11.5	.087
	2 × 4 3 1/2" fiberglass + 1" polystyrene, extruded	16.0	.062
	2 × 6 5 1/2" fiberglass	21.2	.049
	2 × 6 5 1/2" fiberglass + 1" polystyrene, extruded	23.9	.042
Brick veneer	On 8" concrete - 2" polystyrene extruded	11.8	.085
	On 2 × 4 - 3 1/2" fiberglass	13.6	.073
	On 2 × 6 - 5 1/2" fiberglass	20.9	.048
Concrete block or Poured concrete	No insulation with wall board	3.3	.302
	1" expanded polystyrene, extruded	6.1	.165
	2" expanded polystyrene, extruded	10.1	.099
	4" molded expanded polystyrene } beadboard	16.3	.061
	6" molded expanded polystyrene } beadboard	23.5	.043
	1" polyurethane, exterior	8.3	.120
	2" polyurethane, exterior	14.6	.069
	3" polyurethane, exterior	20.8	.048
	4" polyurethane, exterior	27.1	.037
Frame ceiling	2 × 6 with 3 1/2" fiberglass	12.4	.081
	2 × 6 with 5 1/2" fiberglass	18.8	.053
	2 × 6 with 9" fiberglass	30.1	.033
	2 × 6 with 11" fiberglass	36.4	.027
	2 × 6 with no insulation & unvented attic	4.9	.206
Frame floor	2 × 10 with 5 1/2" fiberglass	20.8	.048
	2 × 10 with 7" fiberglass	25.5	.039

Chart A: Heat Transfer Coefficients for Typical Construction (continued)

Windows and Doors

Type	Variations	h ft^2 °F/Btu R	Btu/h ft^2 °F U
Exterior windows	Single glazing	0.91	1.10
	Single glazing with storm windows	2.0	0.50
	Double glazing (.25" air space)	1.72	0.58
	Double glazing (.50" air space)	2.04	0.49
	Double glazing (.50" air space) + storm windows	3.23	0.31
	Triple glazing (.25" air space)	2.56	0.39
	Double glazing (any spacing) + R-1 night insulation	2.86	0.35
	" " " " + R-2 night insulation	3.85	0.26
	" " " " + R-4 night insulation	5.88	0.17
	" " " " + R-8 night insulation	10.0	0.10
Exterior doors	1.5" wood w/o storm	2.04	0.49
	1.5" wood w/ wood storm	3.70	0.27
	1.5" wood w/ metal storm	3.03	0.33
	2" wood w/o storm	2.33	0.43
	2" wood w/ wood storm	4.17	0.24
	2" wood w/ metal storm	3.45	0.29
	1.75" steel w/ fiberglass core	1.69	0.59
	1.75" steel w/ polystyrene core	2.17	0.46
	1.75" steel w/ urethane core	5.26	0.19

Insulative Values of Various Materials

Material	R per inch
Blown fiberglass	2.2
Fiberglass blanket or batt	3.15
Blown cellulose (attic)	3.7
Blown cellulose (wall)	3.3
Polystyrene ("beadboard")	3.9
Extruded polystyrene	5.25
Urea formaldehyde	4.2
Urethane	6.25
Vermiculite	2.2
Blown rockwool	3.3

Guidelines for estimating the R-value of a curtain

Remember that, to enter the combined U-value of the curtain/window combination on the questionnaire, add the R-value of the window itself to the R-value of the curtain and take the inverse of that sum (U = 1/R).

Description of Curtain	Estimated Curtain R-value
No attempt made to seal curtain at sides or bottom	less than R-0.5
Curtain at least moderately well-sealed at sides and bottom and the curtain material itself has no particular insulating qualities. Range of R-value chosen depends on the tightness of the edge seals.	R-0.5 to R-1
Curtain at least moderately well-sealed at the sides and bottom and the curtain material itself has insulative or reflective qualities. The R-value chosen for the curtain assembly equals the R-value of the curtain material plus R-1 for the insulative value of dead air space between the curtain and the window. A dead air space with both surfaces highly reflective to room temperature radiation should be valued R-2; dead air space with one surface highly reflective should be valued at R-1.5. Edge seals must be exceptionally tight or insulating materials must be within 1/4 inch of glazing to achieve an R-value greater than 5.	greater than R-1

Chart B: Heat Loss Factors (Btu/ft h °F)

Below Grade Walls

Depth Below Grade (ft)	Polystyrene Thickness (inches)				
	None	1	2	3	4
2	0.563	0.259	0.168	0.125	0.099
4	0.830	0.431	0.294	0.225	0.182
6	1.01	0.559	0.395	0.309	0.225
8	1.13	0.661	0.479	0.381	0.287
10	1.24	0.747	0.552	0.444	0.343
12	1.33	0.820	0.615	0.500	0.393

Chart C: Heat Loss Factors for Floors*
(Other than Vented Crawl Spaces)

Depth of Floor Below Grade (ft)	Full Polystyrene Perimeter Insulation (none under floor)			
	1"	2"	3"	4"
0	0.55	0.30	0.23	0.15

Depth of Floor Below Grade (ft)	All Other Floor Except Vented Crawl Space-polystyrene thickness below floor			
	None	1"	2"	3"
0	.055	.045	.038	.033
2	.041	.035	.031	.027
4	.032	.028	.025	.023
6	.027	.024	.022	.020
8	.026	.022	.021	.019
10	.025	.021	.020	.018
12	.024	.021	.020	.018

*All values are measured in Btu/ft^2 h °F

Chart D: Infiltration Control Levels

House

Control Level	Description	Air Changes Per Hour*
1	Frame building No vapor barrier No weatherstripping No special attention to sealing	1
2	As above, plus weatherstripping	3/4
3	Plastic vapor barrier Weatherstripping on window and doors	2/3
4	As above, plus Plastic vapor barriers, seams lapped six inches over framing Sill sealer	1/2
5	As above, plus Expanded foam around window and door frames Electrical outlets taped or sealed to vapor barrier	3/8
6	As above, plus No electrical outlets in exterior walls Air lock vestibules on all entrances	1/4

*Air lock vestibules added to any level other than level six may be assumed t increase the level of control by one level.

Basements

If basement below grade, use 1/2 the air changes per hour used for rest

If one wall above grade, " 5/8 " " " " " " " "

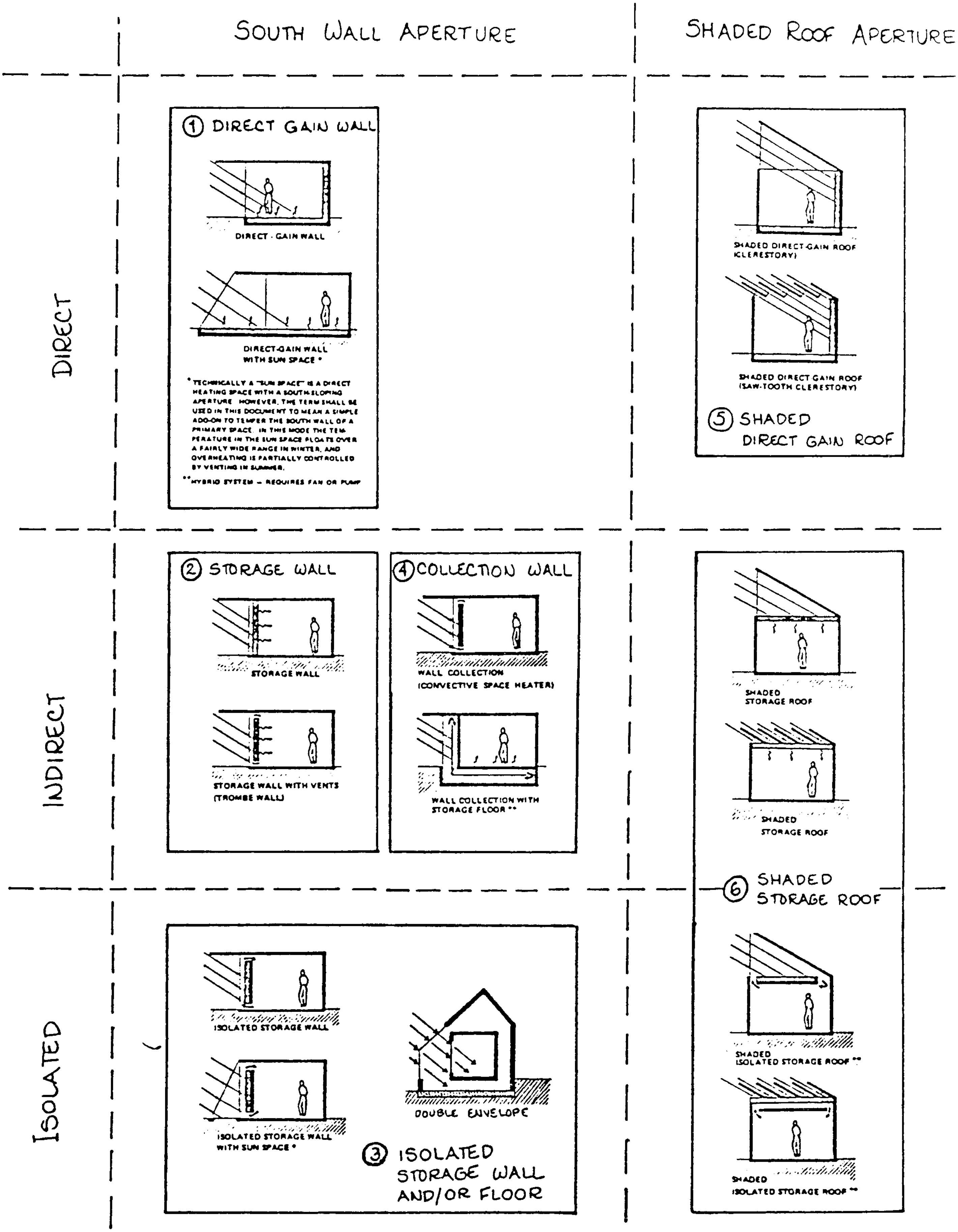
If two walls above grade, " 3/4 " " " " " " " " "

If more than two walls exposed, use same air change rate as used for the res house.

Chart E: Auxiliary Energy Equipment Codes

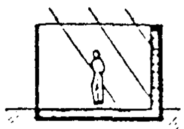
Code	
1	oil-fired hot-air furnace
2	oil-fired hydronic space heating only
3	oil-fired hydronic space heating and domestic hot water combination
4	gas-fired central hot-air furnace
5	gas-fired space heater
6	gas-fired hydronic space heating only
7	gas-fired hydronic space heating and domestic hot-water combination
8	electric hot-air furnace
9	electric resistance heating
10	electric radiant heating
11	heat pump
12	electric air conditioner
13	ventilation fan
14	evaporative cooler with fan
15	oil-fired domestic hot-water heater
16	gas-fired domestic hot-water heater
17	electric domestic hot-water heater
18	wood-fired hot-air furnace
19	wood-fired hot-air furnace and domestic hot-water combination
20	wood-fired hydronic space heating
21	wood-fired hydronic space heating and domestic hot-water combination
22	woodstove or fireplace
23	woodstove and domestic hot-water combination
24	furnace blower
25	hot-water circulating pump
26	humidifier
27	dehumidifier
28	attic ventilation fan
29	solar domestic hot water heating pump
30	active solar space heating system blower
31	other - describe on audit form

Chart F: Passive System Codes - Heating



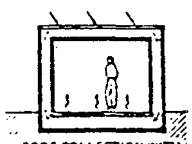
ROOF APERTURE	REMOTE APERTURE

⑦ DIRECT GAIN ROOF



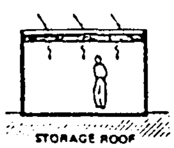
DIRECT - GAIN ROOF (E.G., SKYLIGHTS)

⑨ COLLECTION ROOF

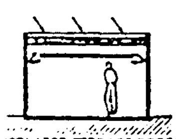


ROOF COLLECTION WITH STORAGE FLOOR **

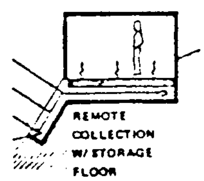
⑧ STORAGE ROOF



STORAGE ROOF



ISOLATED STORAGE ROOF **

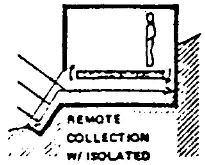


REMOTE COLLECTION W/ STORAGE FLOOR

⑩ REMOTE COLLECTION WITH STORAGE FLOOR

SOLAR POND WITH RADIATIVE FLOOR **

⑪ REMOTE COLLECTION WITH ISOLATED STORAGE



REMOTE COLLECTION W/ ISOLATED STORAGE FLOOR

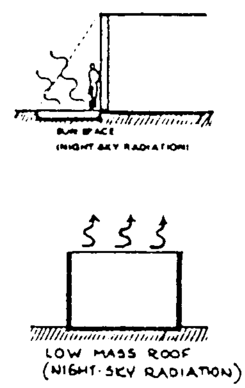
⑫ OTHER

Passive System Codes - Cooling

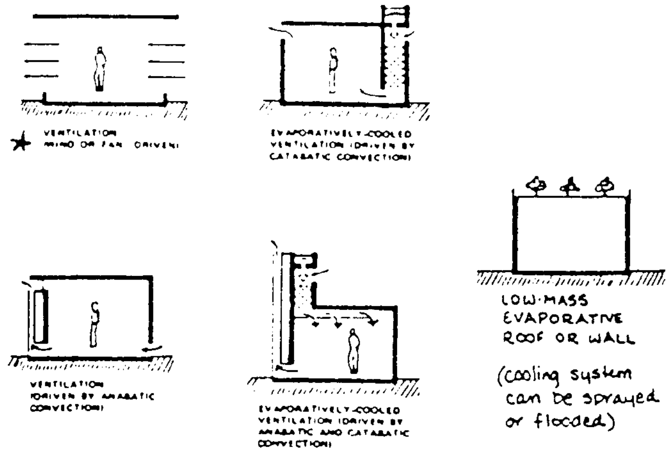
	SKY	ATMOSPHERE
DIRECT	(13) DIRECT RADIATIVE COOLING	(16) DIRECT CONVECTIVE COOLING
INDIRECT	(14) INDIRECT RADIATIVE COOLING	(17) INDIRECT CONVECTIVE COOLING
ISOLATED	(15) ISOLATED RADIATIVE COOLING	(18) ISOLATED CONVECTIVE COOLING

DIRECT

(13) DIRECT RADIATIVE COOLING

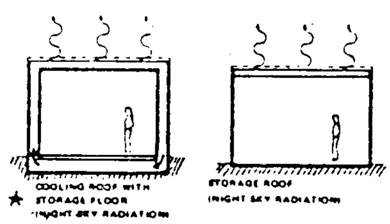


(16) DIRECT CONVECTIVE COOLING



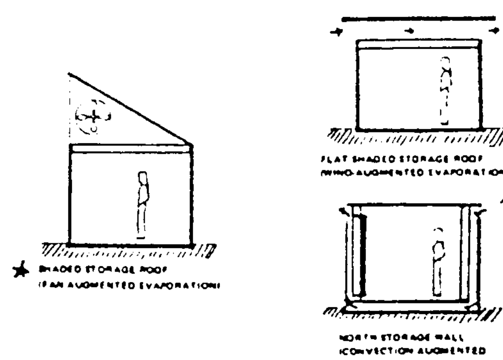
INDIRECT

(14) INDIRECT RADIATIVE COOLING



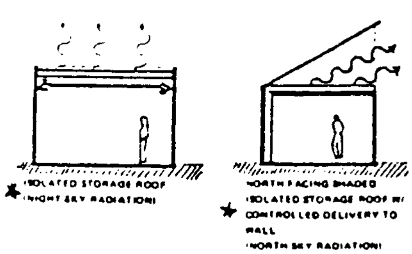
WIND-AUGMENTED EVAPORATION COULD BE EMPLOYED WITH THESE SYSTEMS. cooling surface can be sprayed or flooded.

(17) INDIRECT CONVECTIVE COOLING



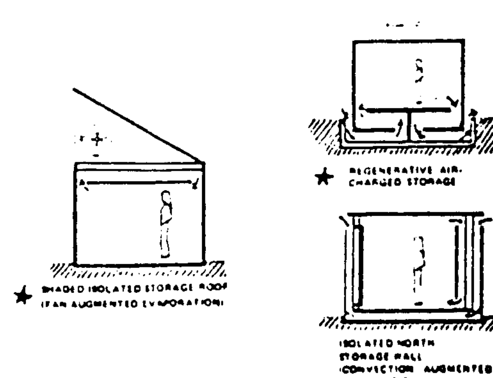
ISOLATED

(15) ISOLATED RADIATIVE COOLING



WIND-AUGMENTED EVAPORATION COULD BE EMPLOYED IN THESE SYSTEMS. cooling surface can be sprayed or flooded.

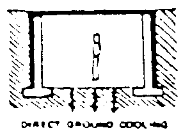
(18) ISOLATED CONVECTIVE COOLING

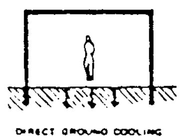


★ HYBRID SYSTEM - requires fan or pump

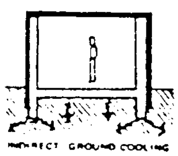
GROUND

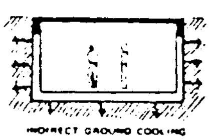
(19) DIRECT GROUND COOLING



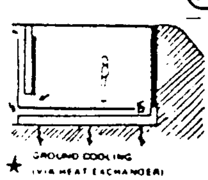


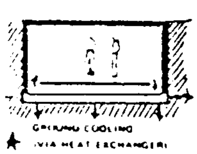
(20) INDIRECT GROUND COOLING

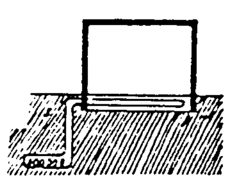




(21) ISOLATED GROUND COOLING



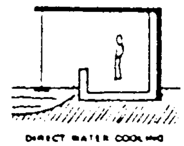




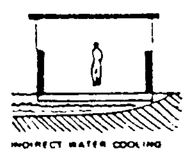
★ THERMAL WELL

WATER

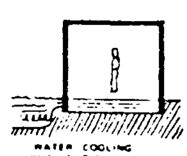
(22) DIRECT WATER COOLING



(23) INDIRECT WATER COOLING

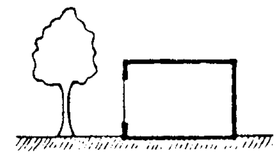


(24) ISOLATED WATER COOLING

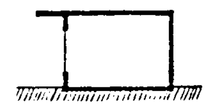


OTHER

(25) DIRECT SHADING

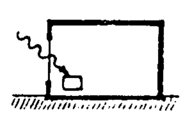


VEGETATIVE SHADING



SHADING DEVICES

(26) SOLAR REGENERATED DESSICANT DEHUMIDIFICATION



A DESSICANT DEHUMIDIFIER

Explanation of Passive Cooling System Codes

Cooling is often thought of as simply reducing the sensible air temperature. In the current context it includes latent cooling (that is, reduction of air humidity), cooling effects achieved by increasing air motion, and cooling of the radiant environment. The three modes of heat exchange (direct, indirect, and isolated) and the four environmental heat sinks to which heat is transferred (sky, atmosphere, ground, and water) are explained below.

Definition of the Three Modes of Heat Exchange

Direct Systems: These systems allow for radiative, convective, or evaporative heat exchange directly from the occupant or occupied space to the environmental heat sink. The heat is transferred directly to the heat sink without passing through a storage element.

Indirect Systems: Heat is transferred from the occupant or space to thermal storage elements and then to the environmental heat sink(s). The thermal mass is in continuous contact with the occupants and interior space and simultaneously in contact with one or more heat sinks. These thermal masses are capable of modulating the amplitude and phase of the temperature fluctuations present in the environmental heat sink(s) used.

Isolated Systems: Heat is transferred from the occupant or space to thermal storage elements and then to the environmental heat sink(s). The difference from indirect is that the thermal mass in an isolated system can be disconnected from either the heat sink, the interior space, or both. Isolation can be achieved by regulating the flow of a heat transfer fluid (usually air or water) or by use of movable insulation. Isolated systems offer the greatest degree of control over interior temperatures.

Definition of the Four Environmental Heat Sinks

Heat Sink	Heat Transfer Mechanism
Sky:	Low effective temperature of the night sky permits radiative heat transfer to the sky under clear sky conditions.
Atmosphere:	a) Where ambient air temperature is not too high, convective transfer of sensible heat can remove heat build-up.
	b) Evaporative process can transfer sensible heat into latent heat of the air, which can then be removed by convection.

Ground: The ground is a large thermal mass at a relatively lower temperature than ambient or building interior conditions during the cooling season. Heat can be transferred to the ground by conduction.

Water: Both surface and aquifer water temperatures are lower than ambient air or building interior conditions during the cooling season. Surface and aquifer waters can remove heat by conduction and convection.

Explanation of the Chart of Passive Cooling System Codes

1) Direct radiative cooling: from sunspace and interior objects direct thorough glazing to night sky
-from low mass roofs coupled radiatively to both the sky and interior space

2) Indirect radiative cooling: from storage roof or from low mass cooling roof or wall coupled to a storage floor
-can include wind-augmented evaporation

3) Isolated radiative cooling: from storage roof or shaded storage roof with controlled removal of heat from interior space
-can include wind-augmented evaporation

4) Direct convective cooling: from windows, vents, duct fans, or by solar chimneys from induced ventilation or other (low mass) solar collectors, in some cases including evaporatively cooled ventilation and/or catabatic convection
-the primary conditions here are natural or induced air motion in shaded ambient conditions

5) Indirect convective cooling: from shaded storage roofs or walls
-convection to cool storage may be wind- or fan-augmented or solar assisted
-can include evaporation from storage surface

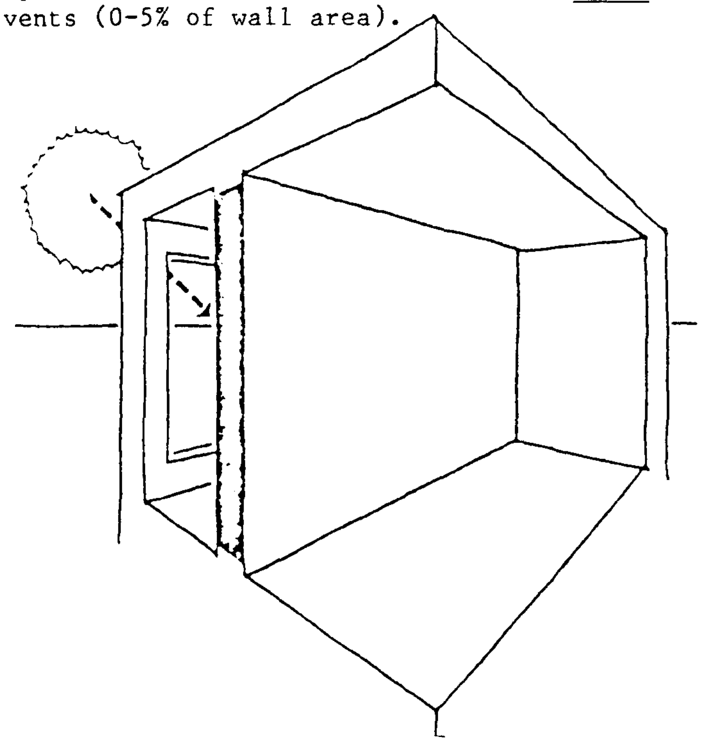
6) Isolated convective cooling: from shaded storage roof or wall or regenerative air charged storage system with controlled removal of heat from interior space
-can include augmented evaporation from storage surface

7) Direct ground cooling:	from the building envelope directly by conduction to the ground. Thermal storage in the building elements is not significant -includes underground buildings and above-ground buildings with the floor elements in direct thermal contact with the ground
8) Indirect ground cooling:	the building envelope includes storage elements that are significant. Heat is lost from the storage through conduction to the ground -includes underground buildings
9) Isolated ground cooling:	from buried air ducts or other heat exchanger in direct contact with the ground -buried air ducts may supply fresh ventilation air
10) Direct water cooling:	the space is cooled directly by a body of water within the space that is connected with an exterior water body
11) Indirect water cooling:	the water body is separated from the living space by an intervening storage mass
12) Isolated water cooling:	cooling is through a controlled heat exchanger to remote cooling ponds
13) Direct shading:	use of vegetation or shading devices to reduce penetration of direct and diffuse radiation to occupied space
14) Solar regenerated desiccant dehumidification:	elements containing desiccant material absorb moisture in air in living space. The desiccant is regenerated by exposure to heat from the sun.

Chart H: Thermal Storage Configuration Codes

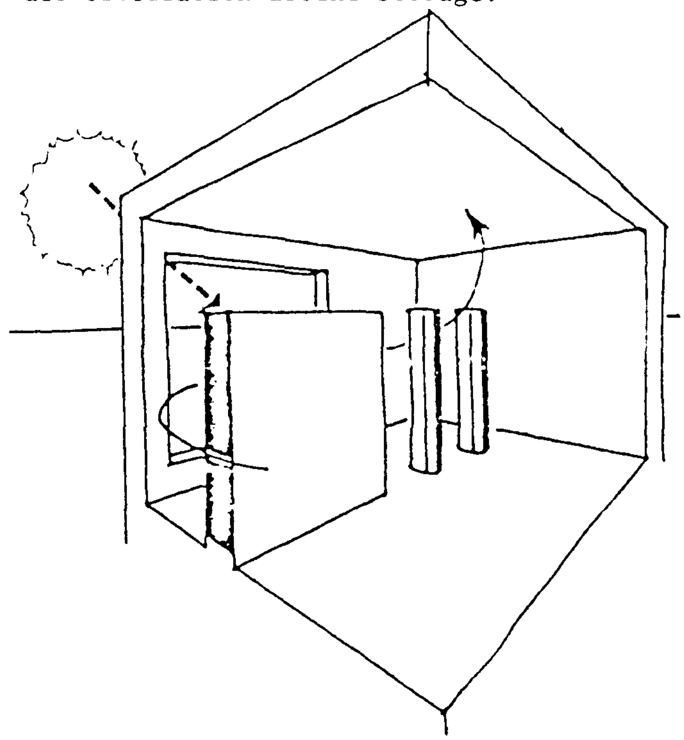
Thermal Storage Pattern (a)

Directly sunlit wall of masonry or water; exposed to living spaces on back side only. Note that sunlit side is isolated from living space. Also includes mass wall with small vents (0-5% of wall area).



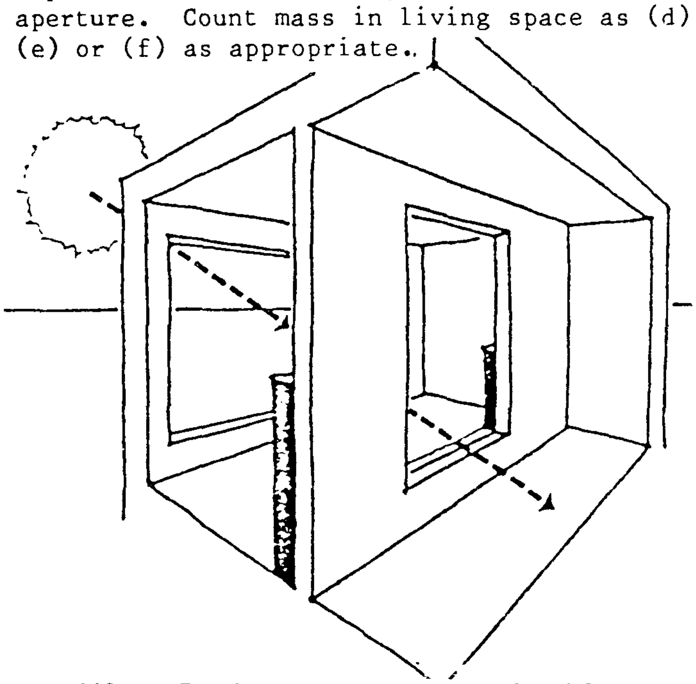
Thermal Storage Pattern (b)

Directly sunlit wall of masonry or water containers; fully exposed on both front and back surfaces to living spaces. Note free air circulation around storage.



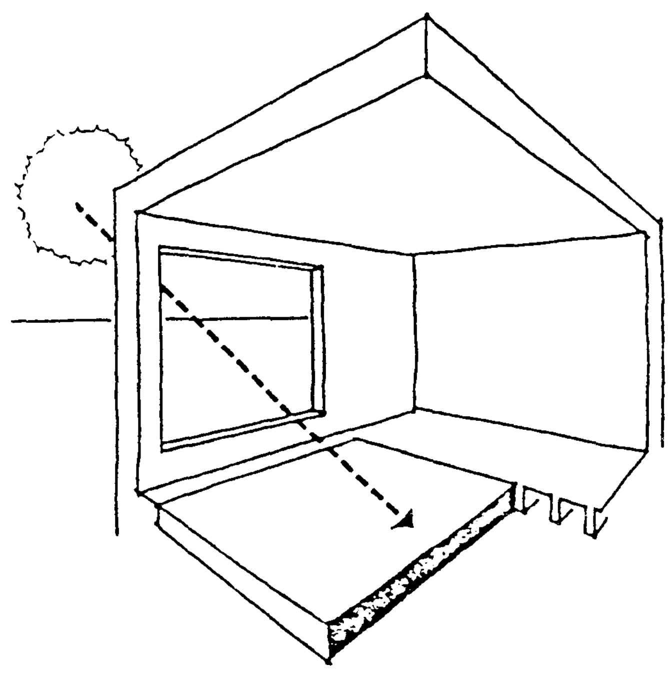
Thermal Storage Pattern (c)

Sunlit mass surfaces in sunspaces; isolated from living space. This pattern applies only to sunspaces which are not kept within 10°F of the living space. Some mass in living space may be directly or indirectly exposed to the sun through connecting aperture. Count mass in living space as (d), (e) or (f) as appropriate.



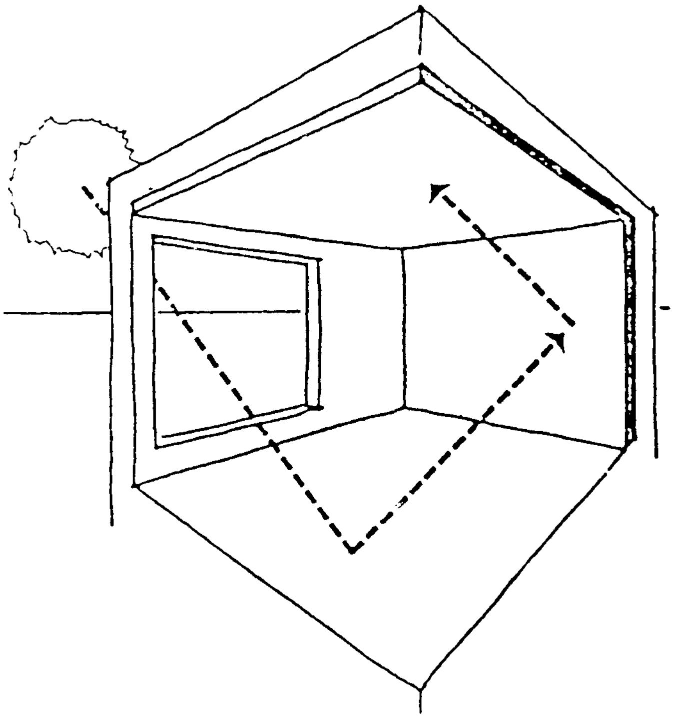
Thermal Storage Pattern (d)

Directly sunlit floor or wall; exposed to living spaces on sunlit face, insulated on other side.



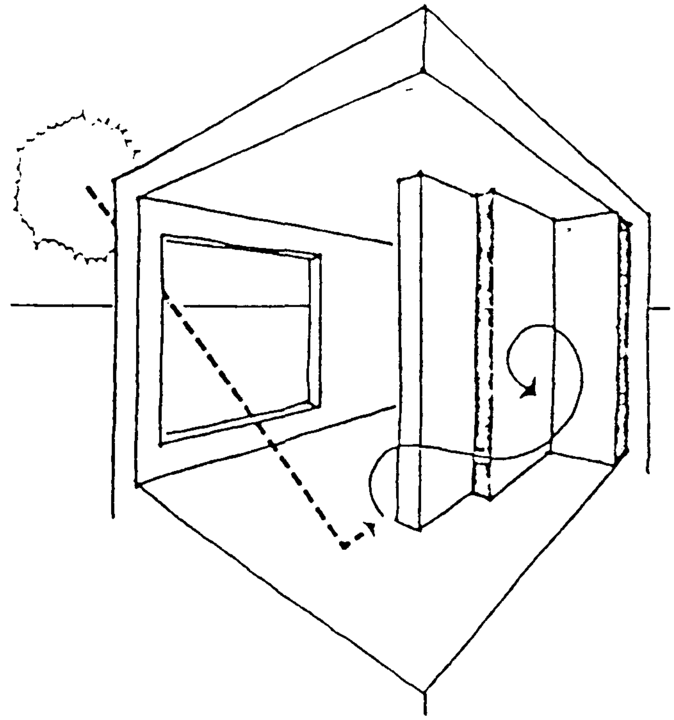
Thermal Storage Pattern (e)

Indirectly sunlit wall, floor or ceiling.



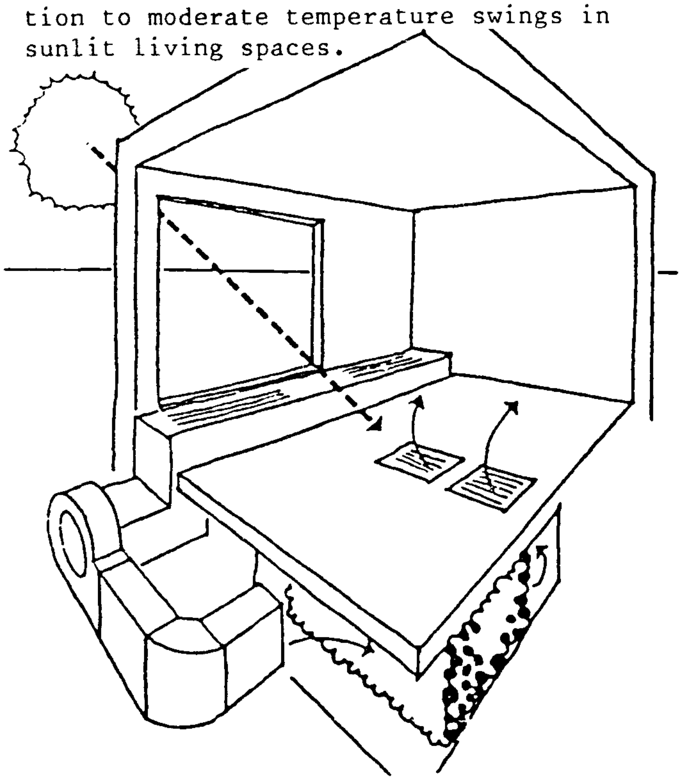
Thermal Storage Pattern (f)

Remotely located wall, floor or ceiling mass; exposed only to heated air from sunlit spaces. No direct solar radiation.



Thermal Storage Pattern (g)

Remotely located, contained mass, operated in combination with fan-forced air circulation to moderate temperature swings in sunlit living spaces.



Thermal Storage Pattern (h)

Directly sunlit mass with no glazing between mass and outdoors.

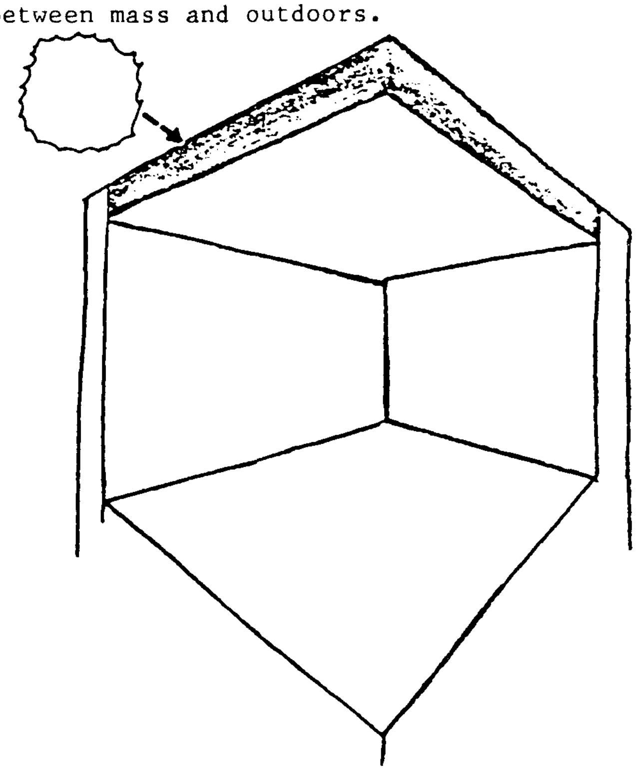
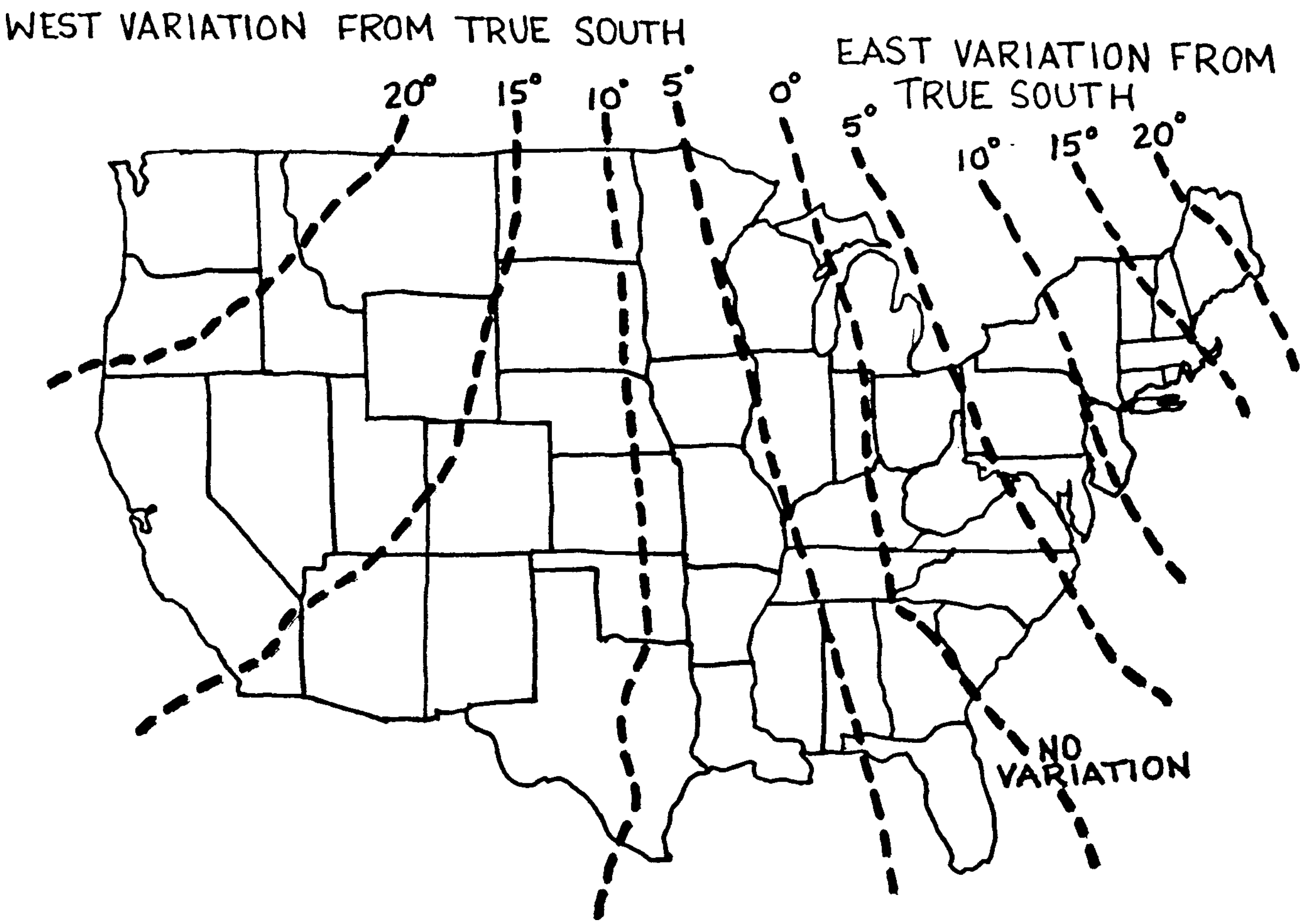


Chart I: Magnetic Variation from True South



Appendix E: Northeast Solar Energy Center's Criteria for Site Selection

NESEC considered the following criteria as a minimum:

- Building must be located within the NESEC jurisdiction
- Building must be used primarily as a residence
- Building must represent design construction and operating characteristics that have the potential for widespread application in the Northeast
- Input data for thermal analysis must be available, including dimensions and descriptions of glazing, building element cross sections, and insulation
- Owners and occupants must be willing to participate in all phases of the study, including site and building inspections, occupant interview, fuel consumption analysis, and documentation
- Building must represent a design that can be duplicated at a present cost of $150,000 or less. Alternatively, if the total building cost would exceed $150,000, the significant passive solar features must be duplicable in lower priced residences
- Building must have an aperture area of at least 10% of the floor area.

NESEC defined these preferred criteria:

- Building incorporates one of the following passive heating systems: direct gain, greenhouse/sunspace, thermal storage wall, or convective loop (other systems would also be considered)
- Building incorporates one of the following back-up systems, in order of preference: a) electric or no backup, b) oil or natural gas and c) wood or coal
- Owners have "conventional" family sizes and lifestyles*
- Sites are near large population centers
- Building does not depend on unique site criteria (cliffs, etc.)
- Building sites have well-documented cost and performance data
- Building sites have well-documented design processes.

NESEC also preferred to stratify its sample by system type, hoping to have represented among its 109 sample sites:

- 40 direct gain, low mass, production homes
- 10 direct gain, high mass, custom-designed homes
- 25 homes with attached sunspaces
- 10 homes with miscellaneous systems (water walls, Trombe walls, etc.)
- 15 retrofits.

In addition, NESEC wanted sample homes to be spread evenly across the region and to represent a variety of climates.

*NESEC did not define "conventional."

Appendix F: Bibliography

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1) Mid-America Solar Energy Complex Region,
2) Northeast Solar Energy Center Region,
3) Southern Solar Energy Center Region,
4) Western Solar Utilization Network Region,
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The findings from the user evaluation portion of the Class C program; each regional report includes an explanation of the methodology used and a copy of the occupants' audit form.

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