AN ANALYSIS OF ENERGY EFFICIENT/PASSIVE SOLAR HOUSING WITH IMPLICATIONS FOR TECHNOLOGY TRANSFER IN OKLAHOMA

By

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PREFACE

The design of energy efficient homes has been my avocation since leaving professional architectural practice in 1980. It has been a unique opportunity to be in the situation where the time is available for an extensive post occupancy evaluation of these homes. I have not intended that these residential projects be judged by current "architectural" theory, for they were designed to avoid architectural gymnastics and fit into the Oklahoma streetscape. If the projects are to be evaluated on the basis of energy efficiency, thermal comfort, and satisfaction provided the owners, there is evidence of success. The owners of the homes were their own interior designers.

Five homes designed by the researcher are evaluated in simple, easily understandable terms, to establish how efficient they really are and, more importantly, to see if the homes helped disseminate the virtues and advantages of passive solar residential design to the persons that have worked on or visited the homes.

A wish to express my sincere gratitude to my clients, the true builders. They had an idea and took the risks. I am particularly indebted to Jan and Roy Montgomery, who have opened their home to countless groups and skeptics. They were the real pioneers of my ideas.

In addition to the home owners, I would like to thank all those who aided in the construction of the homes and the execution and completion of this study. Sincere appreciation is expressed to Dr. Dan Badger for not only chairing my graduate committee, but also for being so available and cooperative in helping me to see this project to completion. I also wish to thank Dr. Sue Williams and Dr. James Lawler for their time and advice while serving as committee members. In addition to the time Dr. Williams has spent on the committee, at some professional risk, I would like to thank her for being a friend and ardent supporter of my ideas for the last six years. If the state is to get the "word" concerning energy efficient homes out to the public, we need a hundred more like Sue.

Neither the work on the homes, nor the work at the University would have been worthwhile without the love and cooperation of my family. I wish to thank my late mother, Esther G. Larson, who taught me the soft and gentle energy paths for as long as I can remember; my sons, Chris and Chad, who taught their old father new tricks on the computer; and my son Kurt and step-daughter Shelly, who are an unending source of pride and good feelings. Finally, to my partner, wife, and best friend, Shirley, goes my eternal gratitude for her loving support and patience.

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CHAPTER I

INTRODUCTION

Some homes in Oklahoma are heated for only three cents per square foot per year, yet new homes are being constructed in which electric heating will cost 10 times that amount. It is feasible to build energy efficient homes in Oklahoma, so why are more not constructed? Why is there very little implementation of the energy efficient building technology in Oklahoma?

In the 1970's, President Carter called the battle for energy independence the "moral equivalent of war." The Congress enacted laws to support and encourage the conservation of energy. The Supreme Court validated the steps taken by Congress. Building and professional engineering and design organizations on the national level wrote prescriptive building standards that were translated into model codes by which builders and design professions could be required to construct energy efficient buildings. Consumer and trade magazines were full of "how to" articles intended to help create a market for energy conservation efficient homes and equipment.

Since 1980, the Reagan administration has cut the budget of the federal agencies having to do with solar research and energy conservation. Regional solar energy centers, funded by the U.S. Department of Energy (DOE), have disappeared. The regional centers promoted energy efficient home construction by working directly with builders, and material and equipment manufacturing associations. The Solar Energy Research Institute, (a DOE agency) Report's blueprint of the U.S. effort to become energy self-sufficent was refused federal funds to be published. The emphasis of the national government has changed. Oklahoma's DOE also disappeared shortly after the Reagan administration came into office.

Nationally, conservation efforts, coupled with the rising energy prices, had remarkable success in reducing the amount of money spent on energy purchases. According to the fiscal year 1984 Lawrence Berkeley Laboratory Annual Report, the U.S. Gross National Product has increased 22 percent since 1973, yet the national primary energy use is actually down by 5 percent (Fiscal Year 1984 Annual Report, 1985). That savings can be equated to $140 billion each year.

Has the energy conservation effort passed by Oklahoma? Has there been a breakdown in the network between the builders, design professionals, educators, and others that is inhibiting the transfer of the skills necessary for energy efficient residential construction? There also seems to be a perception problem with the basic understanding of the meaning of "energy efficiency?" An apparent perception problem is made even more confusing with the "percent energy savings" claims that do not reveal the basis of the savings, the use of cumbersome and misleading verbalizations of techniques, and the showing of photographs of ugly equipment installations that turn off the consumer.

Truth in describing home energy efficiency can be as economically important as "truth in lending" to the home buyer. Simple costs of installation, total utility costs for operation of the home, and clear graphic illustrations are needed to make energy efficienty clearly understood.

Objectives

Many personal, economic, and institutional pressures influence energy efficient technology adoption in the housing industry. This thesis will examine these pressures on energy efficient construction technology. Six case studies of energy efficient homes located in four regions of Oklahoma will be used to establish if a pattern exists. Specifically, this study had the following objectives:

1. to provide a graphic presentation of the "state of the residential energy efficiency art" as it exists in Oklahoma;

2. to derive construction costs and benefits of the case study passive solar/energy efficient houses;

3. to investigate the factors of financial, social, and visual risk that affect the transfer of the energy efficient building technology to the home builders of these case study houses; and

4. to draw conclusions concerning the implications of energy efficient construction as it concerns utility demand, regulation, and educational programs that influence technology transfer in the building trades.

Area of Study

The locations of the homes included in the study are shown on the Oklahoma map (Figure 1). Hugo, Claremore, Medford, and Stillwater are the communities within the state in which the case study homes are located. The different climatic conditions of Oklahoma will affect the energy efficiency of the subject homes. While northwestern Oklahoma is colder than the southeastern Oklahoma, there is more opportunity for solar gain in the northwest because of the fewer cloudy days.

The heating degree days for northwestern Oklahoma (Enid area) is 3971, while the southeastern area has only 3060 degree days. The Public Service Company of Oklahoma (PSO), when assisting builders in the design of heating systems for residential work, uses seven degrees Fahrenheit as the winter design temperature in the Bartlesville area and 14 degrees as the design

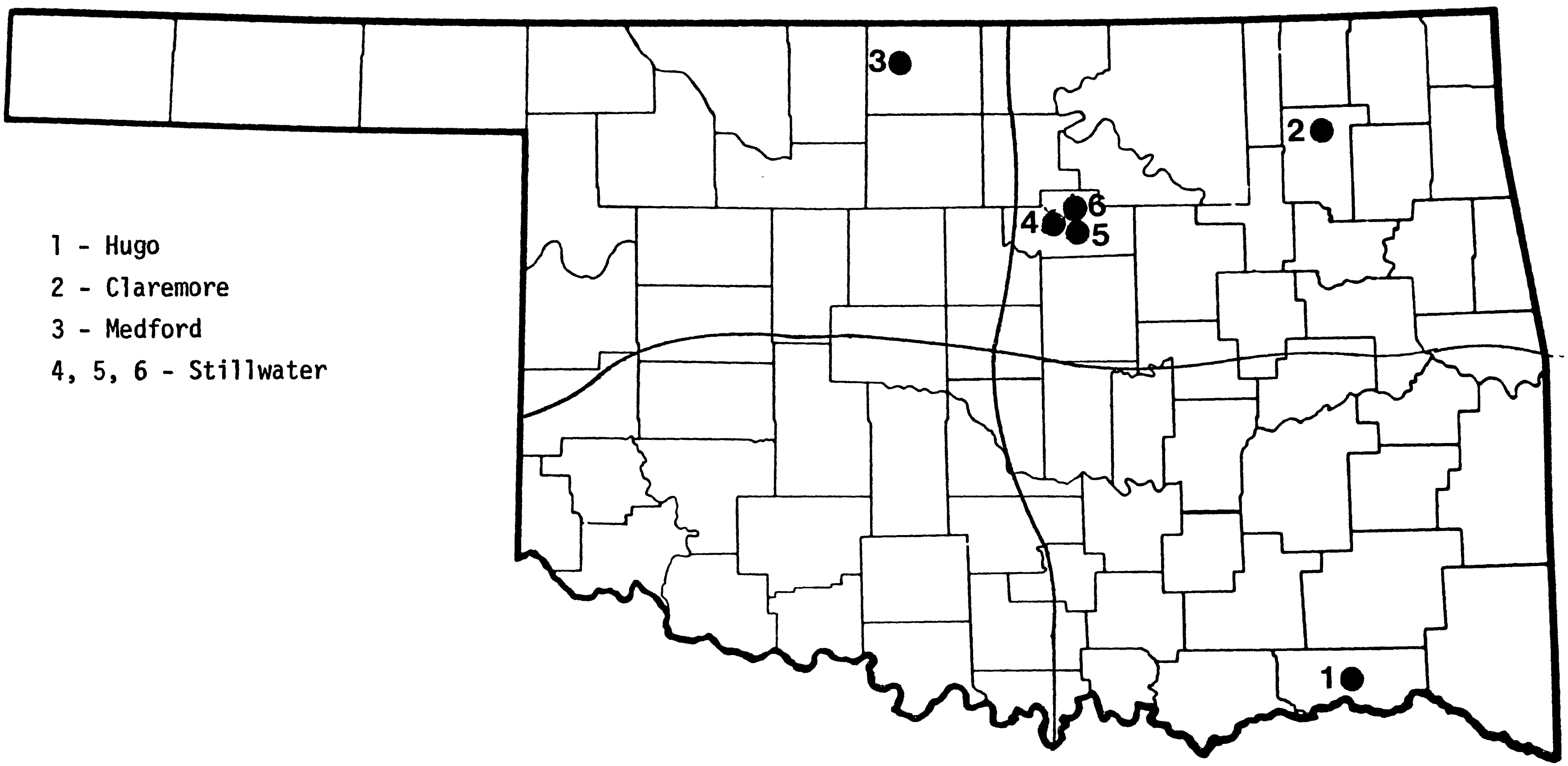

Figure 1. Oklahoma Map, Case Study Home Location

temperature in Hugo. Summer design temperatures are only one degree apart; however, southeastern Oklahoma is much more humid than the northwestern counties.

Organization of Remainder of Thesis

The review of pertinent literature is presented in Chapter II. Chapter III is the procedures chapter; it includes a listing of the areas of inquiry used in the personal interviews with the four housing decision makers (home owners, home builders, mortgage bankers, and utility company representatives). The descriptions or profiles, graphic descriptions, and energy costs for the case study houses are shown in Chapter IV. In Chapter V, the results of interviews that examined attitudes and preceptions of the decision makers are discussed. The summary, conclusions, and recommendations are presented in Chapter VI.

Definition of Terms

Berm. Man-made mound or small hill of earth. The earth hill is placed against the wall of a home to aid in the heating and cooling of the home.

Clerestory. A window that is placed vertically in a wall above the plane of the roof and usually above one's level of vision. The clerestory windows are used to introduce natural light into the building in some place other than perimeter walls.

Cooling Degree Day (CDD). The mean daily temperature minus 65 degrees Fahrenheit. This is used to help forecast cooling requirements. The 65 degree standard, while used by the U.S. Weather Bureau and in this thesis, is not in universal use. Seventy-five degrees is used by many solar engineers to give a more realistic view of when cooling is required (Mazria, 1979).

Daylighting. The practice of utilizing the natural light from the sun or sky to light the interior of a structure. This is a design tool used to reduce lighting and cooling costs.

Degree Day. A measure of the departure of the mean daily temperature from an accepted standard. In this thesis, the standard is 65 degrees Fahrenheit.

Direct Gain. The most simple and frequently used passive solar method used. The system requires only the clear double glass windows as the collector to let the sunlight strike the thermal mass in the space in which it ultimately will be used. The light and heat are both used in the space used by the occupant.

Energy Efficient Home. A home in which the following are used as criteria for design and construction:

a. levels of insulation meet the U.S. DOE recommendations as outlined in the Passive Solar Design Handbook, Vol. 3 (for Oklahoma that would include a minimum R-32 ceiling insulation, R-20 wall insulation, and R-15 perimeter insulation.

b. placement and orientation of windows which take advantage of winter sun angles for winter solar gain while minimizing the effects of unwanted summer solar gain.

c. heating energy efficiency should be less than 3 BTU per square foot multiplied by degree day.

Heating Degree Day (HDD). Sixty-five degrees Fahrenheit minus the mean daily temperature. This is used to help forecast heating requirements. The 65 degree standard is used by the U.S. Weather Bureau and in this thesis.

Indirect Gain. A passive solar system in which the light is transformed into heat in one space by direct gain, and then transported to another space by conduction and/or by convection and radiation. The energy efficient homes in this study utilized a "Trombe wall," which is one example of indirect gain that provides a time delay for the receipt of the solar generated heat.

Kilowatt Hour (KWH). A unit of energy, most often the unit of sale used for electricity, equal to 1000 watt hours. One KWH produces 3413 BTUs of heat energy.

Passive Solar Residential Design. A system or method in which architectural elements are used to collect, store, and distribute energy naturally without the aid of mechanical means. The design discipline also includes the use of architectural and natural elements to prevent the collection of unwanted solar gain and to promote natural cooling.

Purchased Energy Cost. For the purposes of this study, that energy which has been bought from a company in the form of oil, propane, natural gas, or electricity to be used to heat, cool, or operate a device or structure. Energy from the earth or sun acquired at no direct monetary expense is not included.

Retrofit. In the context of this study, the term is used to include remodel, refurbish, replace, or add materials or equipment to an existing structure.

CHAPTER II

REVIEW OF LITERATURE

A 1985 Oklahoma Corporation Commission (OCC) study noted that Oklahoma utilities expected a 34.8 percent increase in electrical demand over the next 10 years (First Biennial Electric System Planning Report, 1985). Even when considering the depressed state of the agricultural and energy based economy in recent years, the utility companies expect to replace the existing natural gas and diesel fuel plants and to increase total capacity with the construction of 20 new power plants to satisfy the state's 1994 demand for electricity (First Biennial Electric System Planning Report, 1985). Although March, 1986 Corporation Commission figures will modify the number of new plants slightly, the increase in projected demand has not changed. Purchased energy is to offset the need for some of the new facilities (Schroeder, 1986). A 1984 Lawrence Berkeley Laboratory (LBL) annual report pointed out that, in the previous 10 years, the number of homes in the nation increased by 27 percent and the amount of office space increased by 32 percent; however, the primary energy use of buildings has increased only 7 percent (Fiscal Year 1984 Annual Report, 1985). Oklahoma is apparently far from the national norm in efforts to reduce energy demand, or the Oklahoma utility companies see a totally different energy demand pattern.

Widespread adoption of the energy efficient residential construction technology could have a significant impact on the electrical and natural gas demand (and revenue flow) of the utility companies. Since the Public

Utilities Regulatory Policy Act (PURPA) regulations were adopted, the Oklahoma utilities have found increased profit in reducing demand. The regulated utilities (which do not include municipal utility organizations such as Stillwater) have advertised and do offer varied programs to inspect and audit existing homes, help the owner pay for installing energy saving improvements, and to reduce summer peak loads by cycling off air conditioning units. The conservation programs of the utilities, with the exception of the PSO "Good Cents" program, do not include effective programs to promote the widespread conservation of energy in new construction. The Oklahoma Natural Gas "conservator home" program, for example, has no inspection or policing of the builder's practices.

The performance measure of energy efficient construction that is generally accepted by building researchers is British Thermal Units per square foot of heated/cooled space and heating or cooling degree days. This provides a nationwide standardized measure of comparison that can easily be converted to cubic feet of natural gas or watts of electricity and then into dollars and cents. The prescriptive description of energy efficiency as used in the building codes is usually "R" or "u" values of insulation, types of windows and doors, and efficiencies of heating or cooling equipment or appliances. Utility companies, consumers, builders, realtors, and energy researchers all have different measuring capabilities and concerns and thus view "energy efficiency" differently.

In response to the "energy crises" of the early 1970's, professional and national code and standards groups published standards that were incorporated into a model energy code. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) published the energy conservation standard "90-75," subsequently revised and labeled "90-80." The ASHRAE standard was largely incorporated into what became known as the national model energy code. The model code ("Code for Energy Conservation in New Building Construction") was jointly prepared by the three major code groups (Basic (BOCA), Uniform, and Southern) in conjunction with the National Conference of States on Building Codes and Standards, Inc. (NCSBCS).

The model code was adopted as law by many states and municipalities as a means to force the builders to use higher levels of insulation and other energy saving practices. Oklahoma, being essentially a non-code state except for the large cities, did not adopt the model energy code. The Oklahoma members of the National Association of Home Builders (NAHB) have resisted any statewide adoption of an energy code or a building code.

The PURPA law of 1978 and the subsequent Supreme Court test (Federal Energy Regulatory Commission v. Mississippi in 1982) did require the state utility regulatory agency, OCC, to consider the adoption of standards that encourage the conservation of energy supplied by utilities. The OCC successfully encouraged the regulated utilities to provide energy audits, peak load management, and load reduction rebates to individual customers.

The many Oklahoma communities with municipally supplied electricity generally do not get the benefits of the OCC mandated conservation programs. The conservation programs offered by the Rural Electric Cooperatives includes energy audits (designed by the Department of Agricultural Engineering at Oklahoma State University) and low interest, federally backed loans, to the energy consumer for energy conserving remodeling or retrofit. The methods and procedures by which these many programs are delivered or are presented to the consumer vary.

The PSO has established a "Good Cents" program in which the plans of new homes are checked before construction for minimal standards of insulation and glazing, heating, and cooling devices. The engineering and duct layout of the heating/cooling systems are checked by the utility. The homes are given a less expensive rate for electricity when the utility verifies, on the construction site, that the energy saving measures are installed in the home as planned and specified. The television advertisement for the "Good Cents" program emphasizes the use of heat pumps for heating/cooling units without any reference to existing natural gas service for economical winter heating.

The U.S. Department of Energy recommended, and the Congress enacted, the use of tax credits to encourage the adoption of energy conserving technology. Many states, including Oklahoma, also enacted energy tax credits. The federal tax credit expired in December of 1985.

In the 1984 NAHB "Buyers Survey," the desirability of a more energy efficient home was rated as the highest motivating factor for buying a new home in all but the first time buyer category. The first time buyers ranked energy efficiency third among the top 15 reasons to buy a new home. The two top reasons were "tired of renting" and "wanted the tax advantage of home ownership" (Fulton, Anton, and Jordan, 1984).

Energy conservation experimentation fortunately has taken place in the housing industry because of the large share of the nation's energy used by housing, the relatively small scale of each investment, and the commonality of the subject (Ribot, Ingersoll, and Rosenfeld, 1982). The literature usually categorizes energy conservation techniques into one of five different methods (active solar, passive solar, super-insulated, earth sheltered, and hybrid).

Active solar for space heating or cooling has not generally gained wide acceptance in residential construction because of first cost, technological, and marketing problems. A few examples of active space heating or cooling have been constructed for demonstration reasons and because of tax credits. Active solar is finding acceptance and use only in the heating of domestic hot water and in certain process applications. Earth-sheltered housing appeals only to a very narrow segment of the market in very few geographical areas. Oklahoma and Minnesota are the states in which a large number of earth-sheltered homes are found. Hybrid techniques are simply combinations of two or more of the techniques. The case study examined two passive solar homes which have partially earth-sheltered walls.

Super-insulation, day-lighting, and passive solar are the energy-saving techniques most in use by builders and the design professions, if an energy-saving technique is used at all. According to Doug Balcomb, a solar energy research leader from the Los Alamos National Laboratory, six to seven percent of new construction in the United States utilizes passive solar techniques (cited in Germer, 1985).

Economic analysis procedures, system performance predictions, and comparison studies are commonplace in the literature. The U.S. Department of Energy, the Lawrence Berkeley Laboratory of the University of California, the NAHB Research Corporation, the Tennessee Valley Authority, and many smaller organizations have studied the instrumentation required and the processes required for standardization of economic studies.

There has always been the apparent need to justify the expenditures to save energy or increase thermal comfort in housing while there is no apparent need to justify the expenditure for the more subjective aspects of comfort in housing, such as thick carpeting, custom cabinetwork, plush furnishings, and other amenities. These amenities in homes which result in additional costs, are frequently marketed for the singular reason of providing additional comfort and convenience to the home owner. The economic studies by the builder and utility organizations have typically omitted any value or benefit for human comfort. It is common for both builders and utilities to address the issue of comfort or the subjective value of amenities when involved in a sales effort. The literature does not address the need to justify additional costs for the builder or the home buyer in the more subjective comfort, convenience, and appearance or aesthetics aspects of housing amenity selection.

The home building industry across the United States and in Oklahoma, in particular, have not generally utilized the design profession except in a few very competitive markets. Home builders commonly use magazine plans and modify them to suit their needs, often without ever sending for the actual working drawing of the plan. To achieve maximum energy efficiency in homes, a certain amount of thoughtful site specific design is required. The Denver area in Colorado has been a good forerunner of the trends in energy efficient housing (Germer, 1982). Denver builders often use architects and design professionals. The large builders who have to concentrate on affordability do not build passive solar homes. These large builders do not see the demand now but they do feel there will be the demand in a few years. The smaller custom builders who build in the $100,000 plus market in nearby Boulder and other exclusive areas are finding passive solar is very marketable. Boulder has an energy code, and that, with the Colorado tax credits, helps to encourage adoption of the technology.

Is energy efficient construction technology considered an innovative technology, subject to the diffusion of innovation rates discussed by Rogers and Shoemaker (1971)? According to Rogers and Shoemaker and also Ostlund (1974), individual perception of the following six attributes of the innovation primarily affect the relative speed a particular innovation diffuses through a social system:

1. relative advantage of perceived superiority to the replaced technology;

2. perceived risk or economic and social loss by failure of the adopted innovation;

3. complexity of difficulty of the technology to understand and use;

4. compatability of the technology with one's values and past experiences;

5. ease of testing the technology, or the extent one can experiment on a limited basis; and,

6. observability or visual risk involved with the technology and social pressures involved, or how visible would success or failure be to others. For example, if a potential user perceives a solar house to be ugly, the user is not likely to use the technology where it can be easily seen and ridiculed by others.

A considerable amount of contradiction, ambiguity, and weak correlations have been found in the research previously done by business and university researchers. Labay and Kinnear (1981) found reason to believe that innovation in the energy and solar field may well be product or situation specific.

Ivan Armstrong (1985), Director of the Construction Trades Curriculum Development and Instruction for the Oklahoma Vocational/Technical Schools, stated in an interview that the focus of the curriculum for the construction trades is the development of trade skills rather than the development of any theoretical knowledge base in the design aspect of construction. The trade skills developed focus on the reading and following of drawings developed by others, not the development of innovation. For example, the Vocational-Technical Schools teach the carpentry trade students how to construct a roof overhang, but they do not teach the students the most energy efficient location for the roof overhang to be placed on the home under construction.

The cost of energy and construction of passive solar/energy efficient homes was examined by Cook (1984). The case study homes included in the Cook study were a part of the First Passive Solar Design Awards Competition of 1980. Many of the homes were not actually constructed; however, projected energy costs were included. The presentation of energy use figures often does not include the total amount of energy purchased by the home owner. Heating, cooling, and water heating costs are extrapolated and shown separately using a confusing assortment of units and methods. Cook showed the auxiliary energy in "total BTUs" or BTUs per square foot.

When considering only heating, energy efficient homes should use less than three BTUs per the product of living area and heating degree days, while tract homes normally use up to 10 (Germer, 1984). In Oklahoma, an equal amount of energy could be expended in cooling the homes.

This study of energy efficient housing is a post occupancy study by the designing architect. The evaluation not only considered dollars as a reason for adoption of the technology, but also considered the subjective motives such as visual impressions and feelings of thermal comfort for technology adoption.

CHAPTER III

METHODS AND PROCEDURES

This study sought to determine the existing practices, attitudes, and perceptions of the persons involved with the construction of what they believe are energy efficient houses. Using structured interviews, questionnaires, and physical measurements, the researcher sought to determine the significant factors that have led to the adoption of energy efficient residential construction technology by the persons involved with the case study houses.

Interview Topics

The following questions were analyzed in interviews with the major decision makers involved in the construction of a home (builders, owners, lending institution officers, and utility representatives):

1. What is the relationship of the construction, orientation, and configuration of each home to the cost of heating and cooling the home?

2. How do the owners, builders, bankers, and utility representatives define "energy efficient residential construction?"

3. Are the decision makers involved with the building project satisfied with the benefits and costs of the project? The costs include construction costs and energy purchased for heating, cooling, and operation of the home. Benefits include comfort, visual success, satisfaction, and savings of dollars compared to an accepted norm of utility expenses for single family residential structures.

4. What sources of information and personal understanding, concerning energy efficient construction technology, do the various decision makers utilize in the process of adopting the technology?

5. What is the perception of the decision makers concerning the value of the conservation of energy and any technical, financial, visual, or social risks involved in the construction of the energy efficient home?

6. If the construction of energy efficient homes is a goal, which individual or group should develop and provide the training? What formal and informal methods should be utilized to implement the training?

7. How do the decision makers interact in the construction process (do the decision makers teach and aid each other in the different aspects of the construction of an energy efficient home)?

8. Are there incentives and housing market factors that affect the home owner's decision to adopt the energy efficient technology?

Case Study Homes

Four energy efficient, passive solar homes designed by the researcher were the main focus of this study. These energy efficient, passive solar homes all had the major percentage of the glass area of the home oriented to the south. A fifth home, in which the researcher had planning input, also is included as a "conventional home." Another energy efficient home that was not designed by the researcher was also included in the study as an example of technology transfer. Brief descriptions of the homes are presented below:

1. The Hugo home is a 3089 square foot, single level ranch style home, with three bedrooms, three bathrooms, two living areas, and other unique features. It is located in Choctaw County in southeastern Oklahoma.

2. The Claremore home is a 2502 square foot ranch style house with three bedrooms, den, "play-room," and two and one-half bathrooms, and also features a step-down living room and sun room. This home is located in a rural setting in Rogers County, approximatley 12 miles northeast of Claremore, in northeastern Oklahoma.

3. The Medford home is a 2246 square foot ranch home with a partial basement, three bedrooms, two bathrooms, large utility room, and central atrium entrance. This home is located in a rural Grant County setting in northwestern Oklahoma.

4. The Stillwater home is a 1516 square foot, single level ranch style home, with three bedrooms, two bathrooms, and a "sun-room." It is located in an urban setting in Payne County in north central Oklahoma.

5. The "Conventional" home is a 1412 square foot ranch style home, built in Stillwater in 1983. Since only limited energy purchases are available for comparison on the technology transfer home, the conventional home, which also was constructed by the same builder of the Stillwater passive solar home, is used to compare utility costs. The conventional home features three bedrooms, two bathrooms, and two living areas. The owner and the other decision makers involved with the conventional home did not fill out questionnaires and are not included in any of the discussion, except for an energy cost comparison in Chapter IV.

6. The home used as an example of the technology transfer utilized in home construction is located in Stillwater, Oklahoma. This home was designed and constructed by J. C. Rogers for the "for sale" market. The home includes 1350 square feet and features three bedrooms and two bathrooms. The home was selected as an example of technology transfer because the builder visited the Stillwater home, listed as number four above, several times. He also visited other energy efficient homes in Michigan,

and his company markets what they perceive to be an "energy efficient home." Only limited energy purchases were available for examination.

Research Methods

The graphic portion of the study includes small scale floor plans and pertinent photographs of each house. Descriptive drawings or photographs are included to explain particularly important features of each house.

Information from the interview was compared to determine if any trends or commonality existed between the persons interviewed (owners, contractors/builders, lending institution officers, and utility company representatives) for each of the homes shown in Profiles One through Four. Building cost data provided by the owner were analyzed to establish cost of construction per square foot of living space. Energy cost data for heating, cooling, and operation of the houses were analyzed to establish the cost of energy per square foot. Energy cost data for each home was secured from the serving utility companies. The most recent 12 to 15 months of data was generally available on the utility company computer systems.

Study participants were assured of confidentiality, in that the participant's names were not used in the report or connected with the data, unless they specifically gave the researcher permission. In an effort to make the report more specific and meaningful, all of the participants except one were willing to allow their names to be used in the study.

Interviews were made "in person," using questionnaires prepared for each group of decision makers. The four different questionnaires had many of the same questions; however, they were slightly different because of the role each person played in the effort to complete the energy efficient home. All interviews were conducted in March, April, and May of 1986.

The case study examination of the homes, owners, builders, and institutions involved, established trends in construction costs, utility usage, thermal comfort benefits, and technology transfer. The examination also pointed to findings that indicated educational and energy policy changes that would foster and encourage energy efficient residential construction.

CHAPTER IV

RESULTS AND DISCUSSION OF ENERGY USE

Introduction to Home Profiles

Owners, builders, bankers, and utility representatives comprise four different groups of decision makers involved with the construction of a single home. The common thread connecting the individuals involved with the construction of the energy efficient home is the owner's determination and willingness to take the perceived financial and social risks involved in the construction of a home utilizing a technology that does not have wide use in the state of Oklahoma. The owners of the four energy efficient homes served as the contractor for much of the construction, in that they all purchased materials from various suppliers and arranged for work to be done by the major trades. The homes described in the following profiles (one through four) are in four different regions of the state (see Figure 1, Chapter I).

One home, shown in Profile Six, was included as an example of how energy efficient residential technology is transferred. The contractor/owner perceived that he built an energy efficient, passive solar home. The builder marketed the home as "super insulated with passive solar," featuring the latest technology in home construction. The builder of the "technology transfer" home admittedly is still learning how the sun and the climate works, even though he has been in the housing construction business for 15 years. The technology transfer home is located in Stillwater, Oklahoma. Rogers Construction Company builds custom homes, is also a land developer, tract home builder, and real estate sales company. They generally only build homes within a subdivision developed by the company.

A conventional home, shown in Profile Five, also was included in the study to serve as an energy use comparison. The conventional home also was located in Stillwater, Oklahoma. The owner of the conventional home was aided by the thesis researcher in the development of the floor plan. However, the window types and sizes, insulation levels, and other building construction details were left to the discretion of the owner and builder to maintain a strict construction budget. The conventional home was constructed by the same builder utilized to frame the Stillwater home. The builder, Shelton Construction Incorporated, (SCI), has the reputation of building a quality custom home. SCI does not build speculative or tract homes. A tabulation and graphic description of the pertinent facts concerning each of the homes used in this study is presented on the following pages:

Profile One

The Hugo Home (see Figures 2-7)

Owners: Roy and Jan Montgomery

Address: Goodland Route, Hugo, Oklahoma 74743

Date of First Occupancy: March 12, 1983

Living Area: 3089 Square Feet

Garage Area: 918.6 Square Feet

Construction Cost: $120,000 (not including land)

Cost per Square Foot: $38.84 (construction cost/living area)

Auxiliary Heat Source: Two Electric Heat Pump Systems

Alternative Energy Source: Fireplace in the living room that allows for circulation of heated air through the duct system of one of the heat pump units.

Utility Company: Public Service Company of Oklahoma (Brad Roberts)

Last 12 Months Utility Costs: $1741.17 (June, 1985 - May, 1986) (30,400 kilowatt hours)

Mean Cost of Energy Per Month: $145.10

Mean Monthly Energy (all electric-kilowatt hours): 2533

Mean Cost of Energy per Square Foot per Month: $.0470

Mean Cost of Electricity for Non-Heating or Cooling Month (an approximation of lighting, cooking, clothes drying, water heating, and refrigeration costs): $83.09

Mean Heating or Cooling Costs per Month: $62.01

Heating and Cooling Costs per Month per Square Foot: $.0201

Insulation Levels:

Ceilings (vaulted): R-30 (flat): R-38

Exterior Walls: R-19 (batt) + R-5 (sheathing)

Perimeter Slab: R-10

Area of South Facing Glass:

Direct Gain: 287 Square Feet

Indirect Gain: 98 Square Feet

South Facing Glass Divided by Living Area (includes indirect gain Trombe wall): 12.46%

Home Builder: Owner contracted with Melvin Inge (retired) of Sawyer, Oklahoma, to provide carpentry labor and supervision of the other trades on an hourly basis. Buster Pugh of Hugo, Oklahoma, was Mr. Inge's assistant on the job.

Lending Institution: Federal Land Bank Association (Don Chitwood), Durant, Oklahoma

The owner has been having a great deal of trouble with the heat pumps. For the last year, the heating mode has been usable in the emergency (resistance heating) mode only. The average monthly cost for the first year of operation was $114, when the heat pumps were operating correctly.

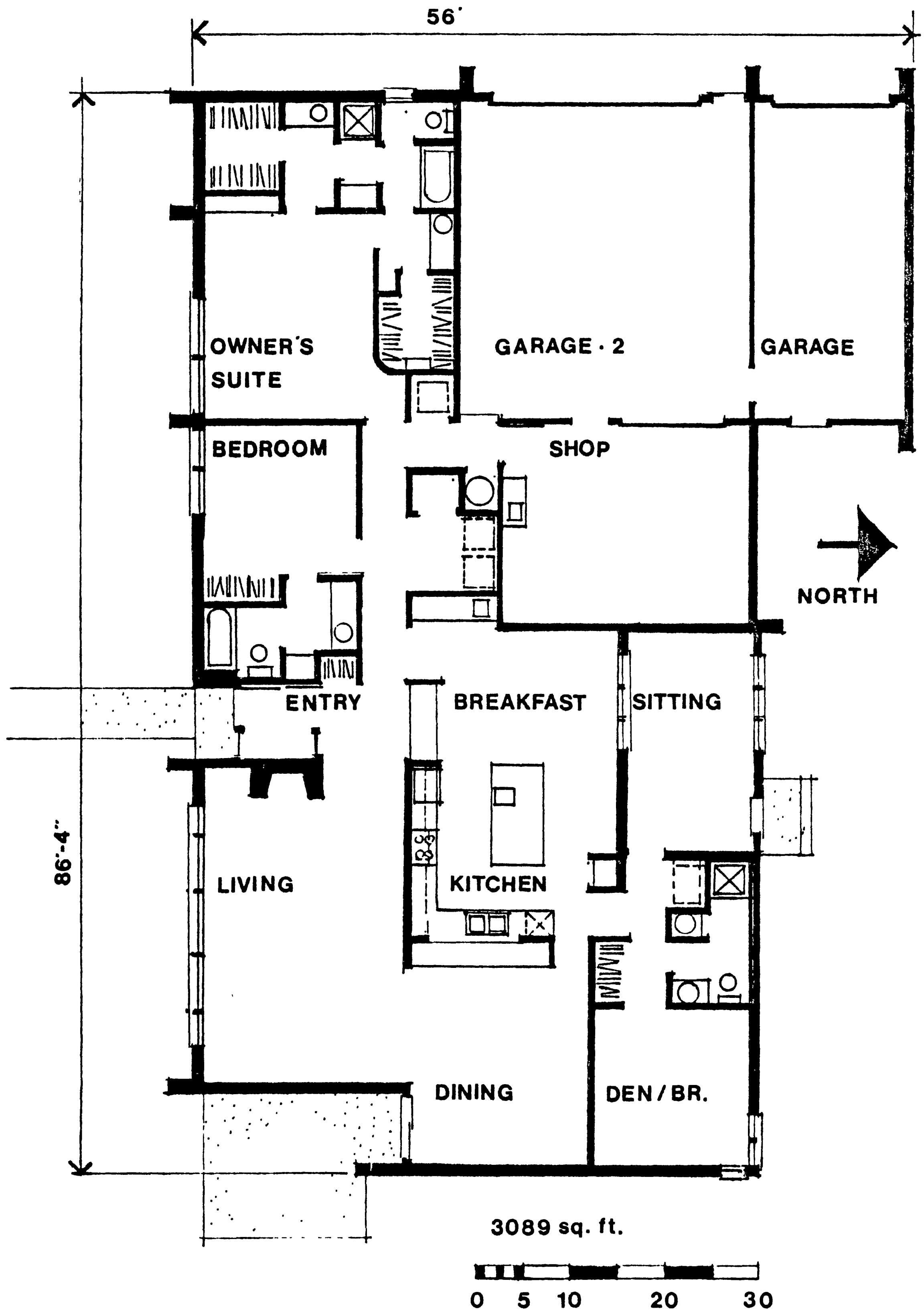

Figure 2. Hugo Home, Floor Plan

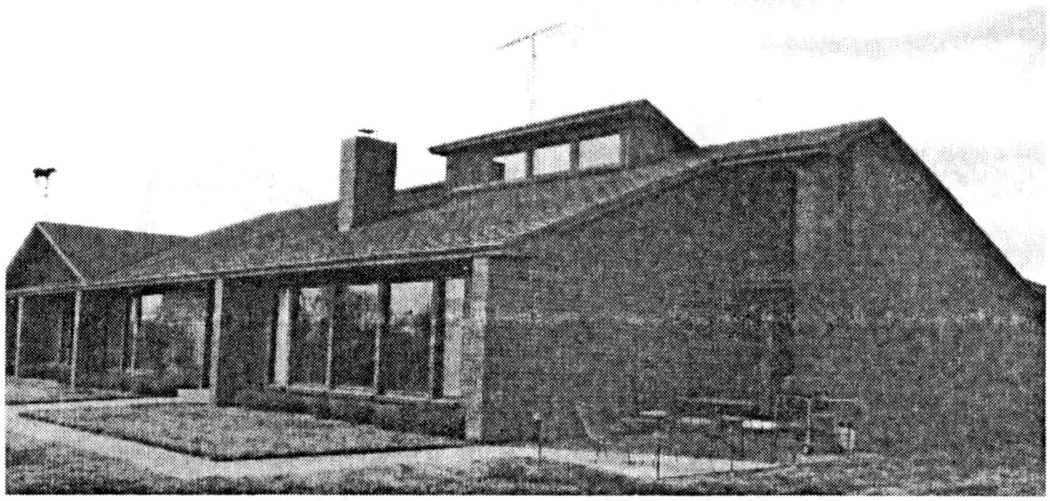

Figure 3. Hugo Home, Exterior, South and East Sides

Figure 4. Hugo Home, Trombe Wall, Exterior

Figure 5. Hugo Home, Living Room

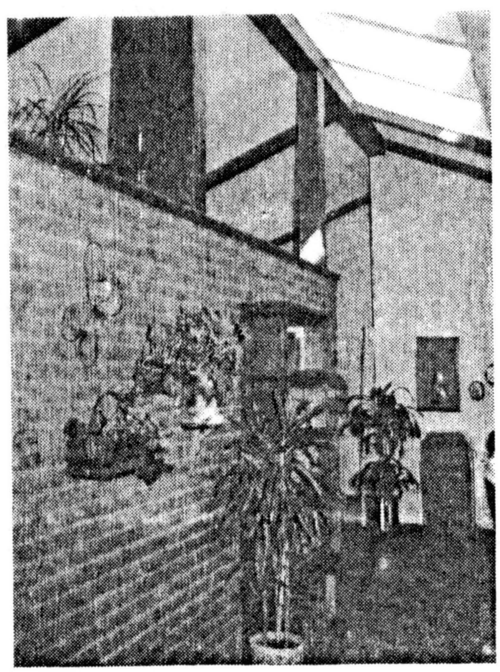

Figure 6. Hugo Home, Living Room,
View Showing Clerestory

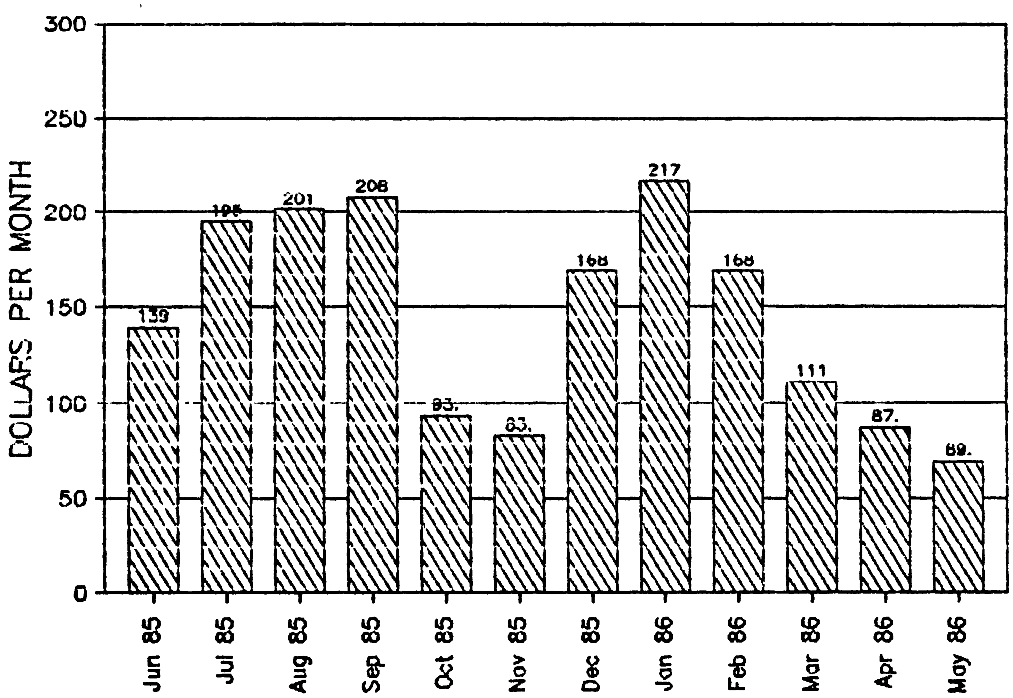

Figure 7. Hugo Home, Monthly Total Energy Costs

Profile Two

The Claremore Home (see Figures 8-11)

Owners: Steve and Bonnie Watson

Address: Box 248, Route 4, Claremore, Oklahoma 74017

Date of First Occupancy: May, 1985

Living Area: 2502 Square Feet

Garage Area: 621 Square Feet

Cost of Construction: $75,000 (not including land)

Cost per Square Foot: $29.98 (construction cost/living area)

Auxiliary Heat Source: Carrier High Efficiency Heat Pump

Alternative Energy Source: Wood burning stove with capability for circulating that heat through the heat pump (air handling unit) duct system and a small wood burning stove in the living room.

Utility Company: Verdigris Valley Rural Electric Cooperative, Collinsville, Oklahoma (Kent Coulter)

Cost of Energy Since Occupancy: $1236.78 (June, 1985-May, 1986) (18988 kilowatt hours)

Mean Monthly Energy Use (all electric kilowatt hours): 1582

Mean Cost of Energy per Month: $103.06

Mean Cost of Energy per Month per Square Foot: $.0412

Mean Cost of Electricity for Non-Heating or Cooling Months (April and October) (an approximation of lighting, cooking, clothes drying, water heating, and refrigeration): $78.63

Approximate Heating or Cooling Costs per Month: $24.43

Heating and Cooling Costs per Month per Square Foot: $.0098*

---

*The heat recovery device on the gas and liquid lines between the outside condensing unit and the inside coil is currently installed incorrectly, thus causing an energy drain on the system. As a result, this figure is not accurate and should not be considered representative.

Insulation Levels:

Ceiling (vaulted): R-30 (flat): R-38

Exterior Walls: R-19 (batt) + R-5 (sheathing)

Perimeter Slab: R-10

Area of South Facing Glass:

Direct Gain: 383 Square Feet

Indirect Gain: 39 Square Feet

South Facing Glass Divided by Living Area: 16.86% (includes the indirect gain Trombe wall)

Home Builder: The owner contracted with Ewin Burns of Claremore, Oklahoma to provide carpentry labor, concrete work, and some coordination of other trades.

Lending Institution: Federal Land Bank Association, Broken Arrow, Oklahoma (Jeff Thomas)

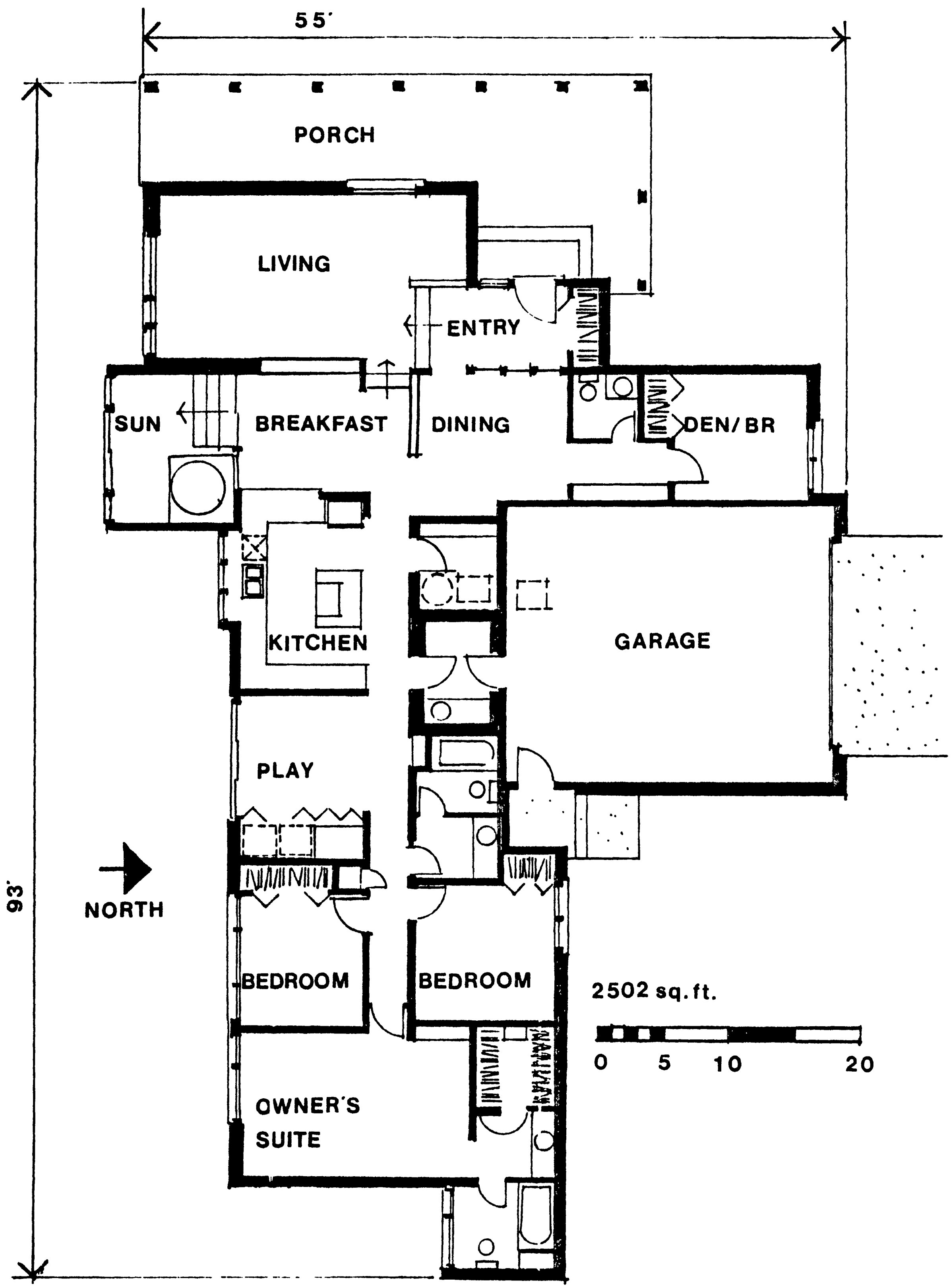

Figure 8. Claremore Home, Floor Plan

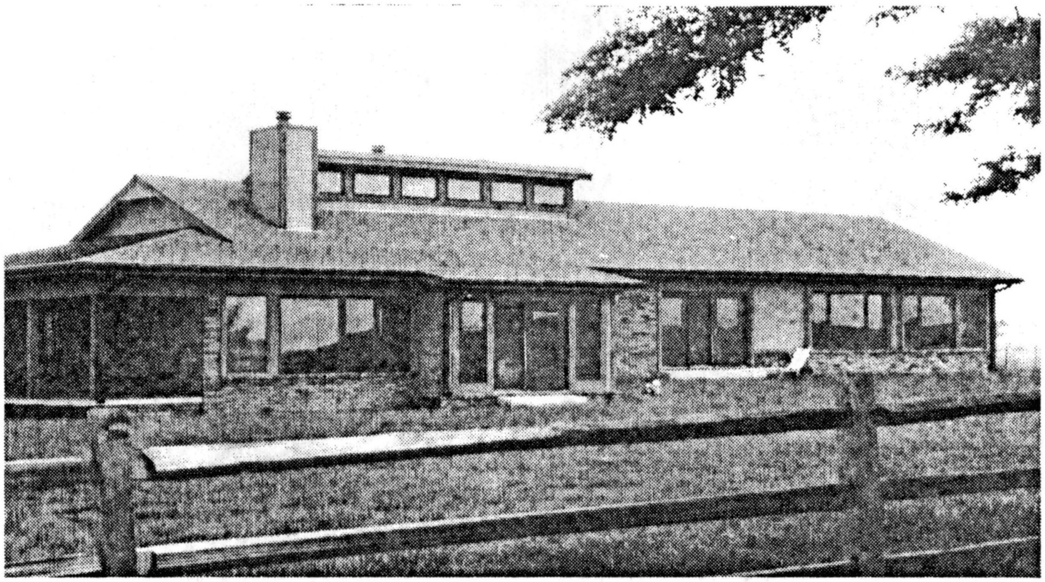

Figure 9. Claremore Home, Exterior, South and West Sides

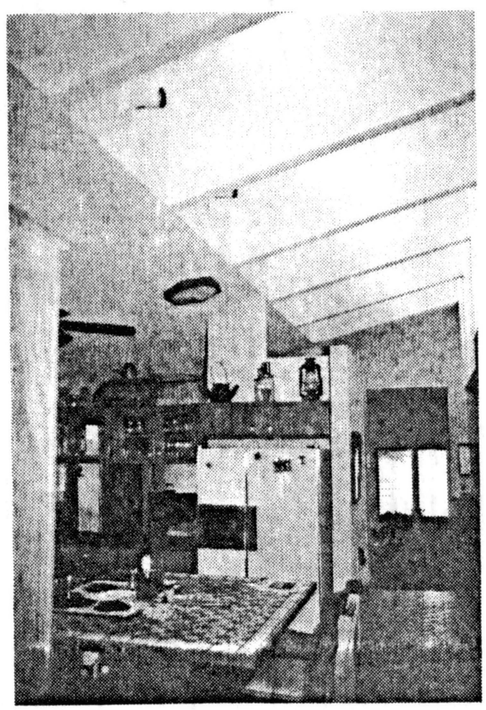

Figure 10. Claremore Home, Kitchen, With Clerestory

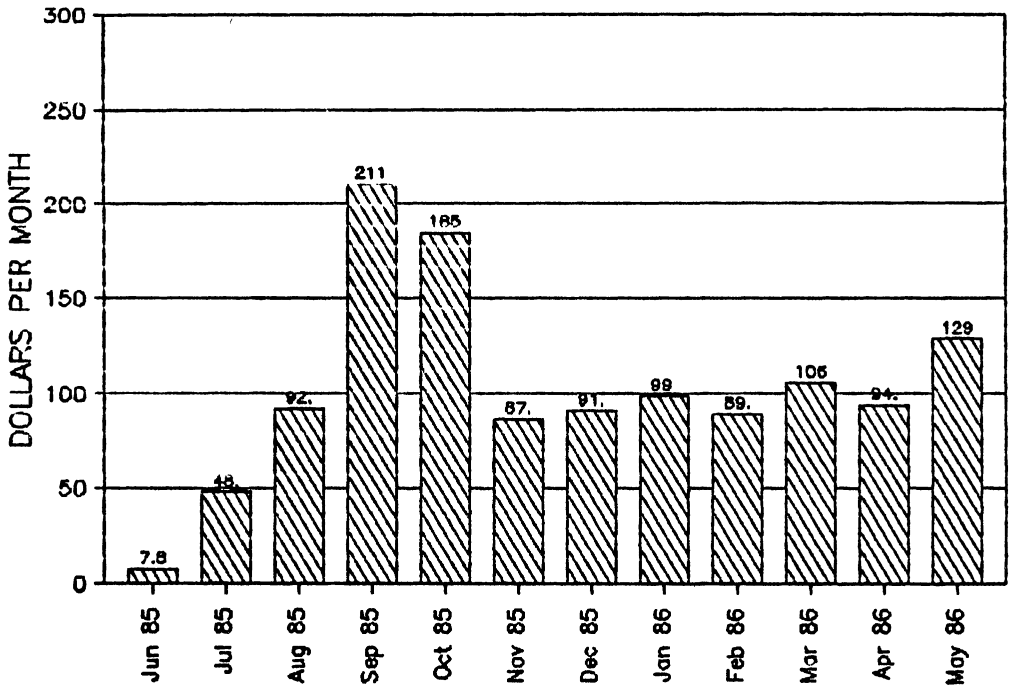

Figure 11. Claremore Home, Monthly Total Energy Costs

Profile Three

The Medford Home (see Figures 12-15)

Owners: Les and Dee Renner

Address: Route 2, Box 10-F, Medford, Oklahoma

Date of First Occupancy: May, 1983

Living Area: 1942 Square Feet (includes exterior and interior wall area)

Atrium Area: 304 Square Feet (entrance and hot tub area)

Total Area Used for Calculations: 2245 Square Feet

Garage Area: 621 Square Feet

Basement Area: 900 Square Feet

Cost of Construction: $54,000 (not including land)

Cost per Square Feet: $24.80 (construction cost/living area + atrium)

Auxiliary Heat Source: Natural Gas Furnace

Alternative Energy Source: Wood burning stove in the living room (60 cubic feet of wood per season, approximately one cord)

Utility Company: ARKLA (Natural Gas), Blackwell, Oklahoma (Morris Lawson); Oklahoma Gas and Electric Company, Enid, Oklahoma (Ken Smith)

Last 12 Months Utility Costs (June, 1985 - May, 1986)

Natural Gas: $139.17 22,700 cubic feet

Electricity: $938.80 (13761 kilowatt hours)

Mean Cost of Energy per Month: $89.83

Cost of Energy per Square Foot per Month: $.0400

Mean Cost of Electricity for Non-Cooling Months (an approximation of lighting, cooking, drying, and refrigeration costs): $64.93

Mean Cost of Natural Gas in Non-Heating Month (an approximation of water heating costs): $10.36

Mean Cost of Heating or Cooling per Month: $14.54

Heating and Cooling Costs per Month per Square Foot: $.0065

Insulation Levels:

Ceiling (vaulted): R-30 (flat): R-38

Exterior Walls: R-19 (batt) + R-5 (sheathing)

Perimeter Slab Insulation: R-10

Area of South Facing Glass:

Direct Gain: 223.6 Square Feet (including atrium)

Indirect Gain: 120 Square Feet

South Facing Glass to Living Area Percentage: 11.53%

Home Builder: Les Renner, owner contracted, the owner also provided much of the work in construction

Lending Institution: Current mortgage held by Kingfisher Savings and Loan Association, Kingfisher, Oklahoma (Kenneth Wehrenberg)

Water heating is done with natural gas, using a demand type (tankless) heater. The gas furnace has not been used, except when the owners are on vacation. The owner has purposely turned off the furnace so that any heat required will be provided by the wood stove.

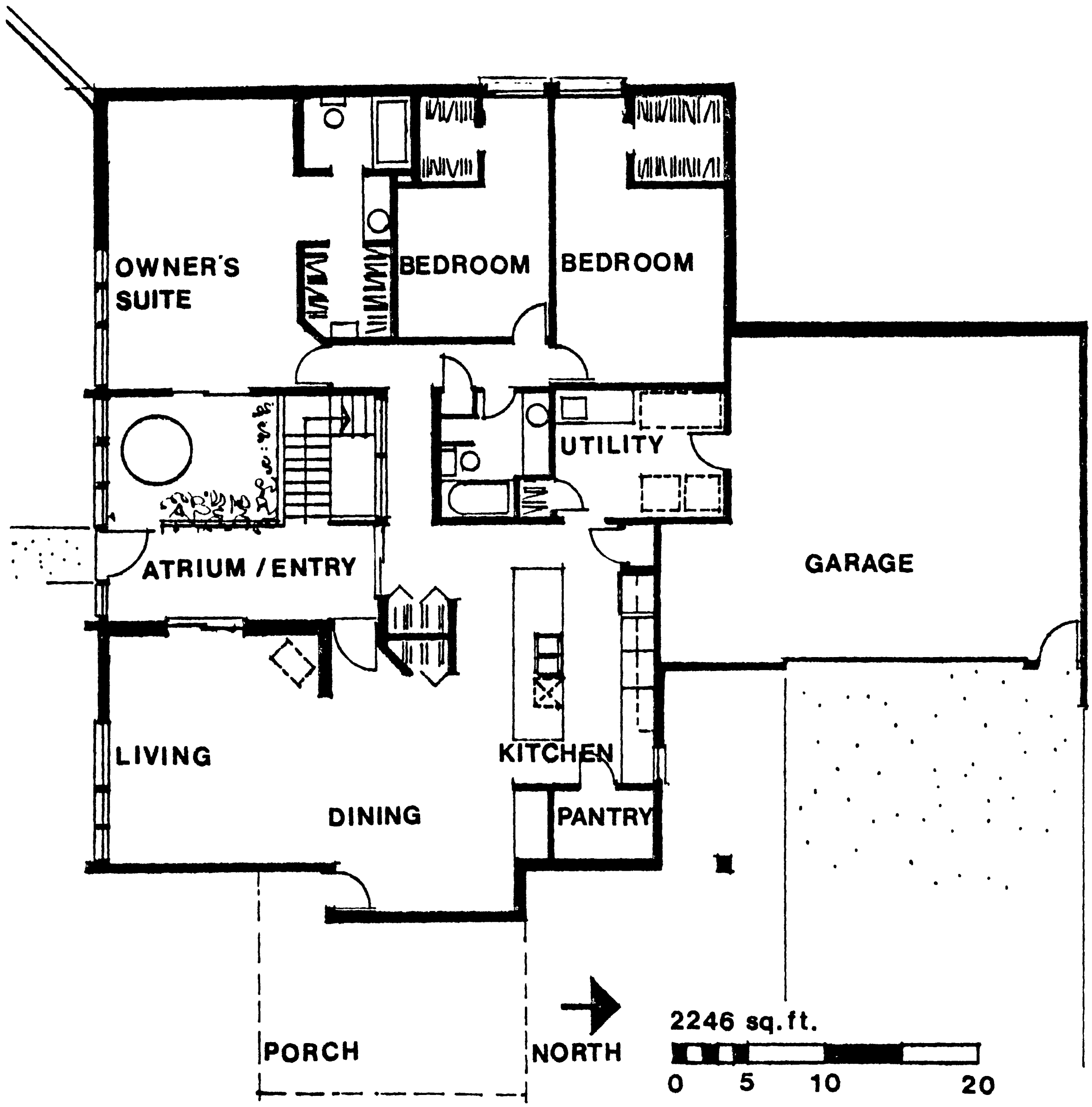

Figure 12. Medford Home, Floor Plan

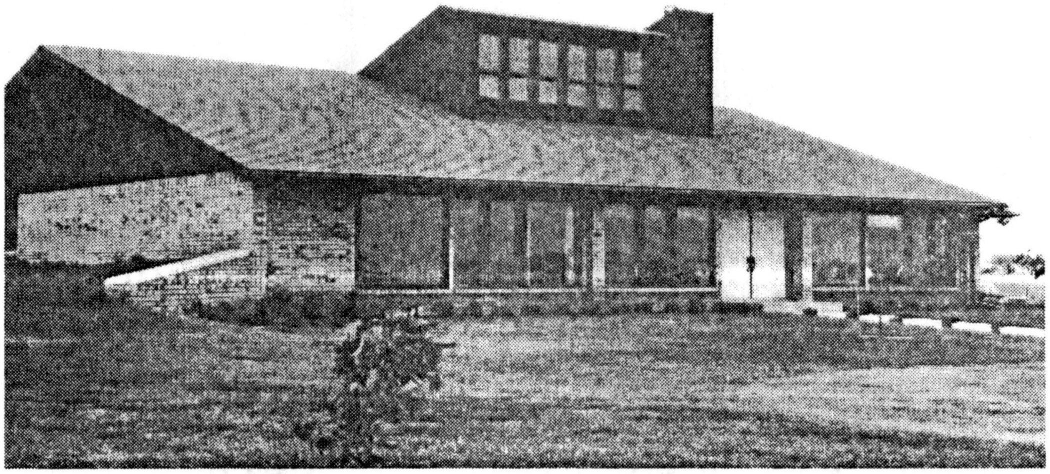

Figure 13. Medford Home, Exterior, South and West Sides

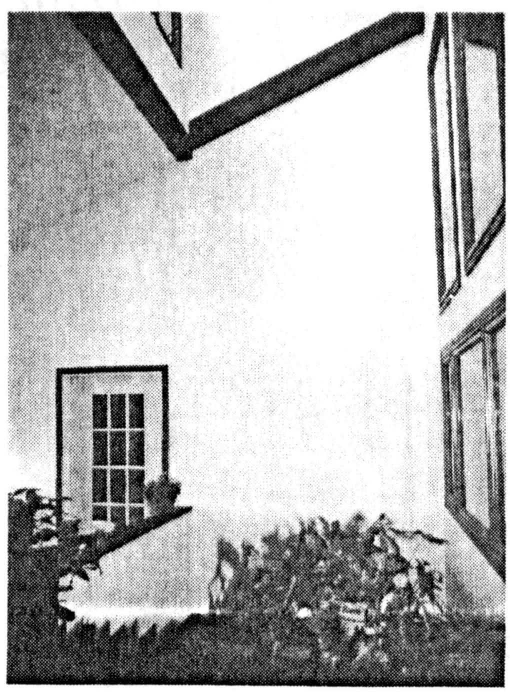

Figure 14. Medford Home, Atrium
Entry Clerestory

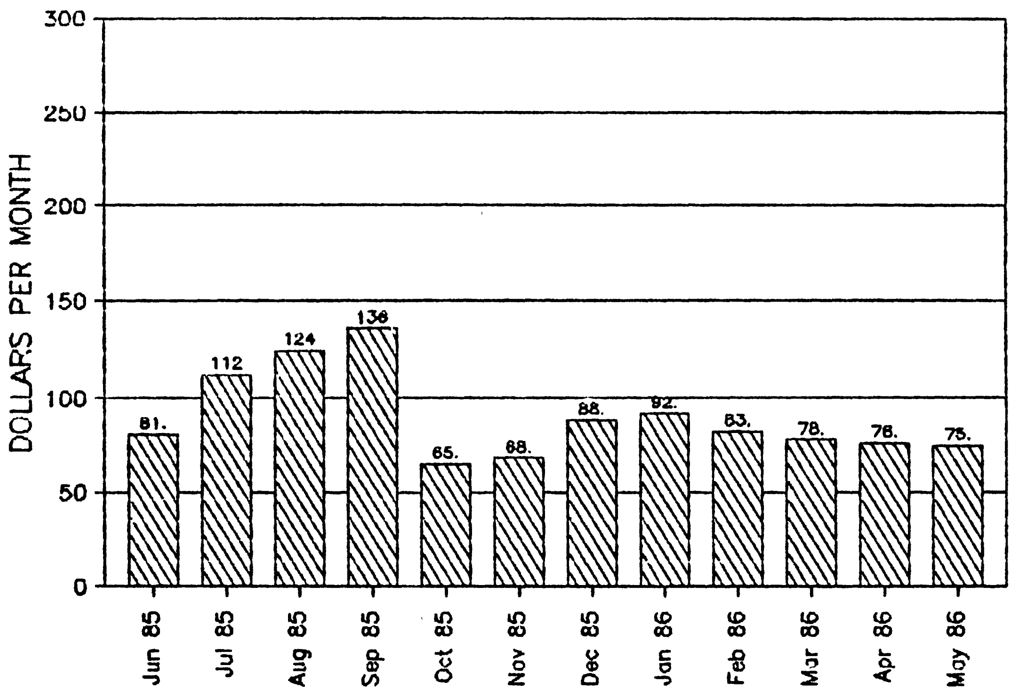

Figure 15. Medford Home, Monthly Total Energy Costs

Profile Four

The Stillwater Home (see Figures 16-24)

Owners: Ken and Shirley Larson

Address: 107 W. Redbud Drive, Stillwater, Oklahoma 74075

Date of First Occupancy: September, 1984

Living Area: 1516 Square Feet

Garage Area: 529 Square Feet

Cost of Construction: $83,380 (not including land)

Cost per Square Foot: $55.00 (construction cost/living area)

Auxiliary Heat Source: Carrier high efficiency natural gas furnace with a high efficiency air conditioning condensing unit and coil. Water heater is a 40 gallon natural gas tank heater.

Alternative Heat Source: Wood burning stove in living room in which there were eight to ten fires during the past year.

Utility Companies: Oklahoma Natural Gas, Stillwater, Oklahoma (Barbara Bivens); Stillwater Municipal Utility (Electricity)

Total Utility Costs for 12 Months: $6-8.45

Natural Gas: $166.25 26,100 cubic feet (June, 1985 - May, 1996)

Electricity: $442.29 (5,516 kilowatt hours) (June, 1985 - May, 1986)

Mean Cost of Energy per Month: $50.71

Cost of Energy per Square Foot per Month: $.0334

Mean Cost of Electricity for Non-Cooling Months (an approximation of lighting, cooking, drying, and refrigeration costs): $26.66

Mean Cost of Natural Gas for a Non-Heating Month: $9.51

Mean Cost of Heating or Cooling per Month: $14.55

Heating and Cooling Costs per Month per Square Foot: $.0096

Insulation Levels:

Ceiling (vaulted or flat): R-48

Exterior Walls: R-19 (batt) + R-5 (sheathing)

Exterior Perimeter Below Grade: R-15

Concrete berm walls with R-15 insulation extends to 3'10" above floor level on the north, east, and west sides

Area of South Facing Glass:

Direct Gain: 202.5 Square Feet

Indirect Gain: 72 Square feet

South Facing Glass Divided by Living Area: 18.1%

Home Builder: Owner contracted, except that Shelton Construction, Inc. provided materials and provided concrete and framing labor.

Lending Institution: Liberty Federal Savings and Loan Association, Stillwater, Oklahoma (Bruce Brown)

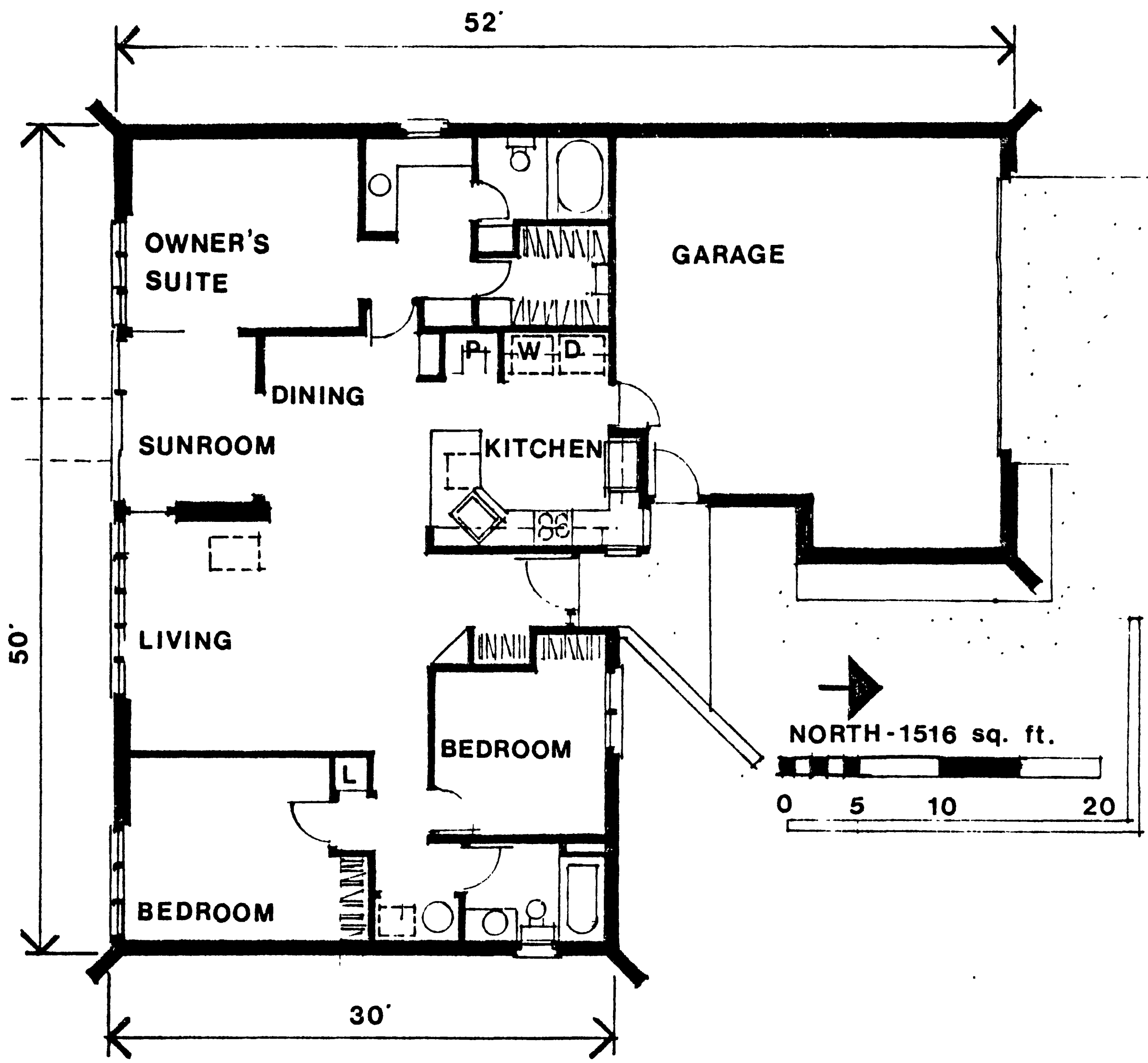

Figure 16. Stillwater Home, Floor Plan

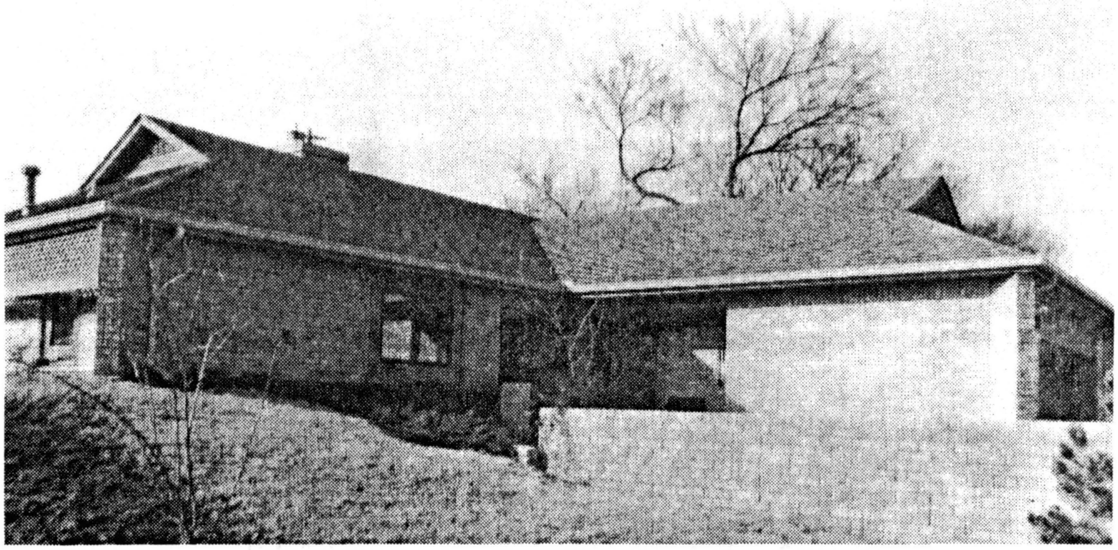

Figure 17. Stillwater Home, Exterior, North and East Sides

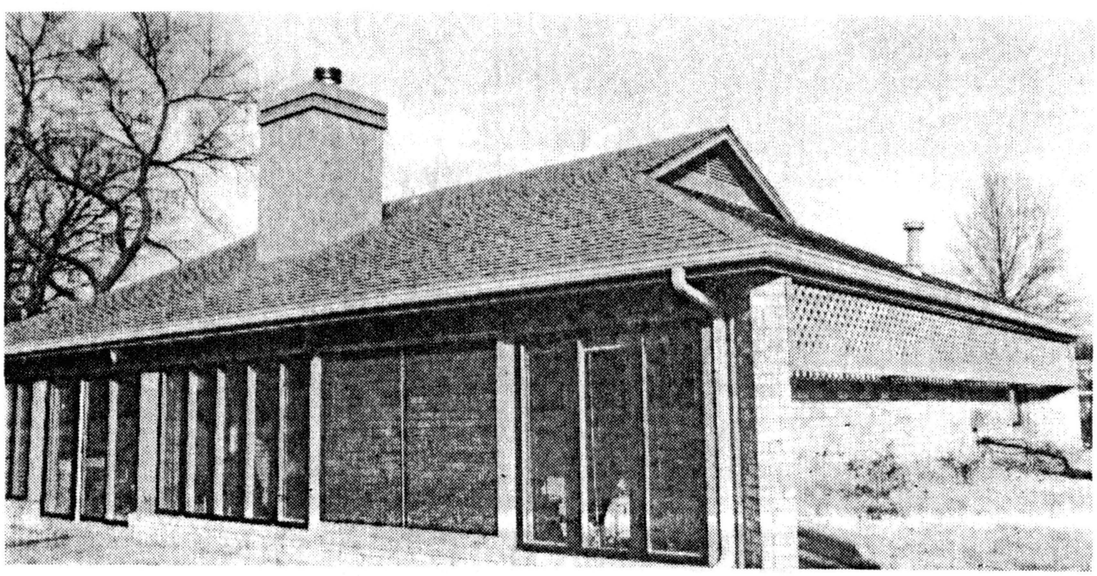

Figure 18. Stillwater Home, Exterior, South and East Sides

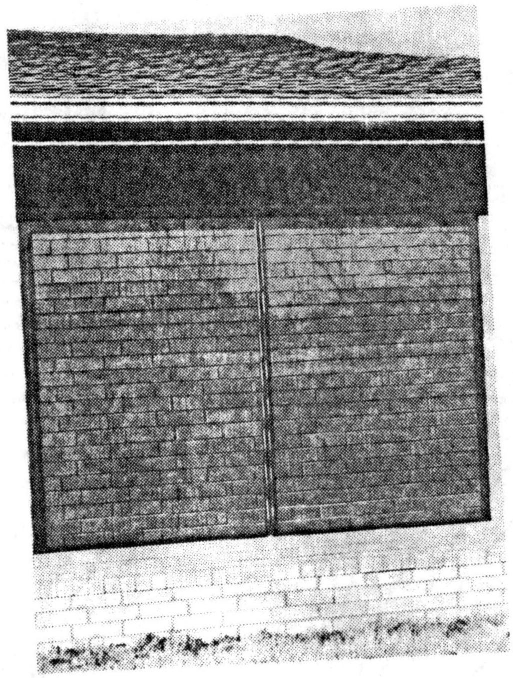

Figure 19. Stillwater Home, Trombe Wall Exterior

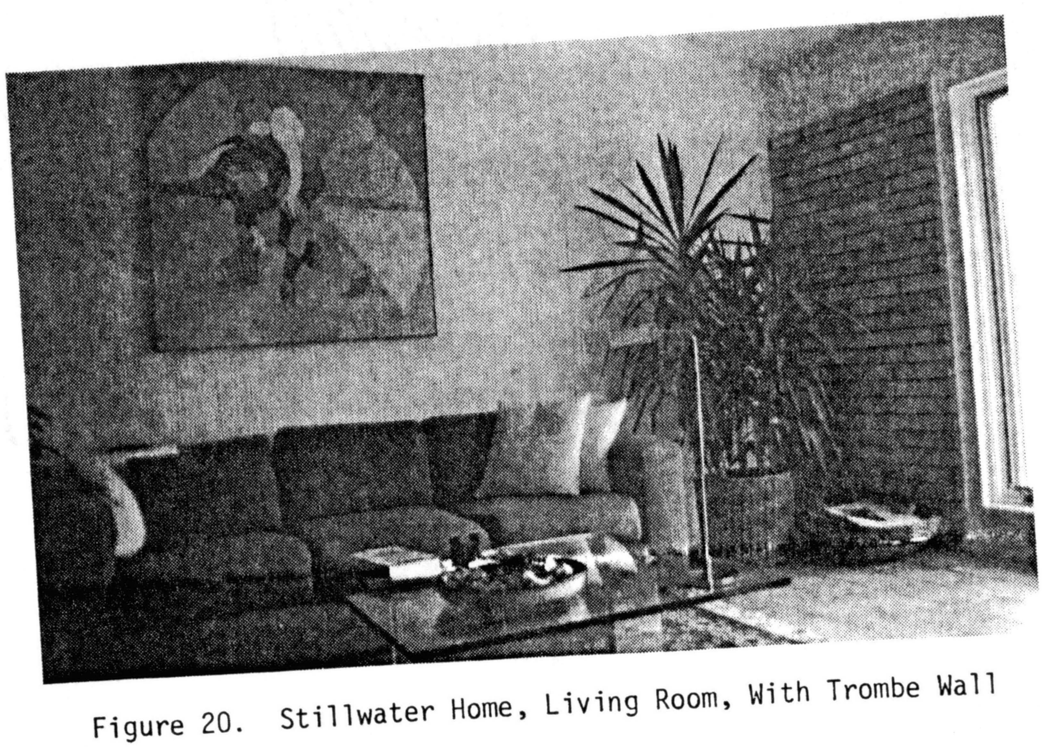

Figure 20. Stillwater Home, Living Room, With Trombe Wall

Figure 21. Stillwater Home, Sun Room

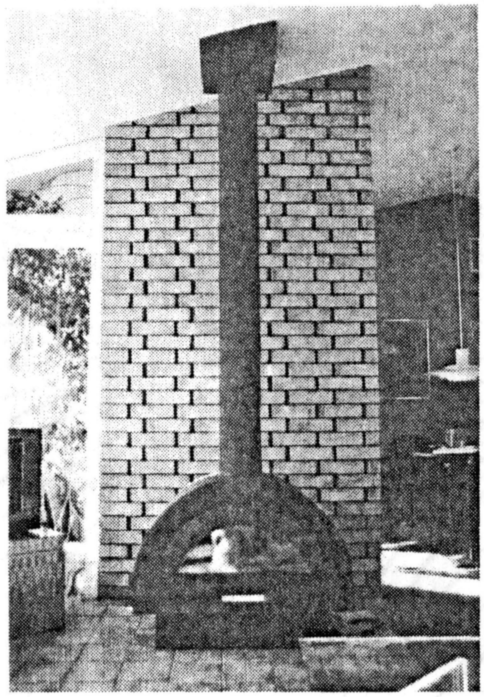

Figure 22. Stillwater Home,
Wood Stove

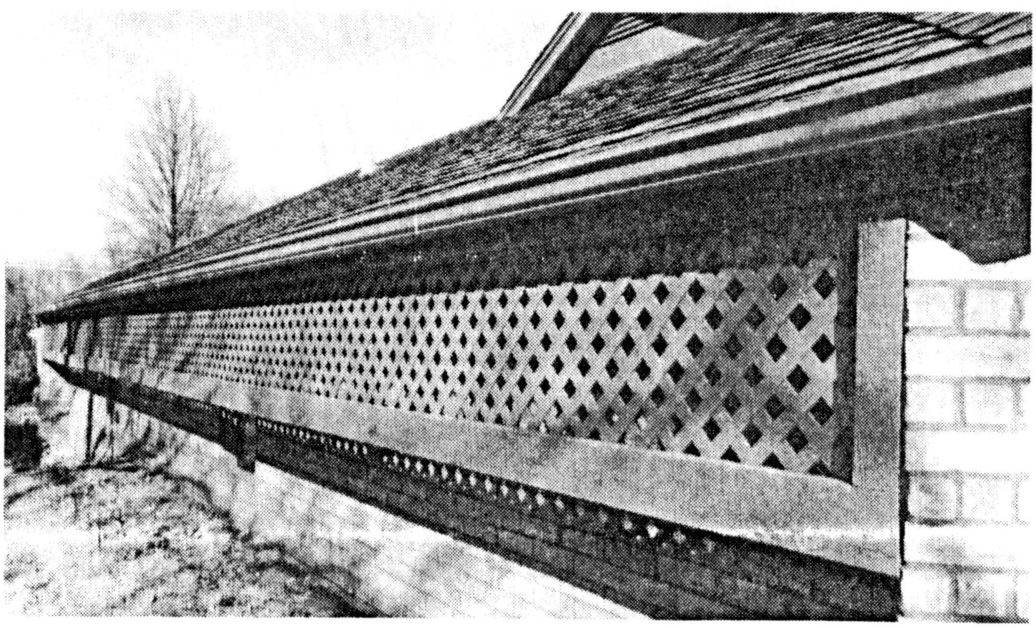

Figure 23. Stillwater Home, West Wall Shading

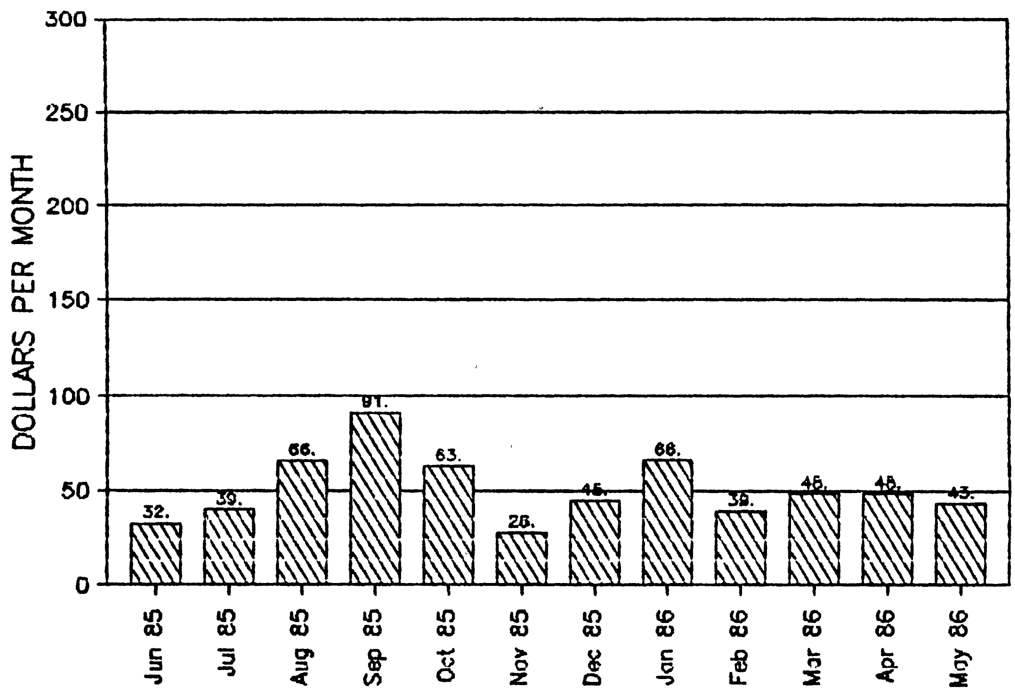

Figure 24. Stillwater Home, Monthly Total Energy Costs

Profile Five

The Conventional Home (see Figures 25-26)

Owner: Not to be Listed

Address: 1703 Berkshire, Stillwater, Oklahoma 74074

Date of First Occupancy: January, 1983

Living Area: 1412 Square Feet

Garage Area: 455 Square Feet

Cost of Construction: $55,000 (not including land)

Cost per Square Foot: $38.95 (construction cost/living area)

Auxiliary Heat Source: Natural Gas Furnace

Alternative Energy Source: Fireplace

Utility Companies: Central Rural Electric Cooperative, Stillwater, Oklahoma (Bill Blair); Oklahoma Natural Gas Company, Stillwater, Oklahoma

Total Utility Costs for 12 Months: $1528.31 (June, 1985 - May, 1986)

Natural Gas: $385.68 76,400 cubic feet

Electricity: $1142.63 (14232 kilowatt hours)

Mean Cost of Energy per Month: $127.36

Cost of Energy per Square Foot per Month: $.0902

Mean Cost of Electricity for Non-Cooling Months (an approximation of lighting, cooking, drying, and refrigeration costs): $62.33

Mean Cost of Natural Gas for a Non-Heating Month: $19.80

Mean Cost of Heating or Cooling per Month: $45.64

Heating and Cooling Costs per Month per Square Foot: $.0324

Insulation Levels:

Ceiling (vaulted or flat): R-38

Exterior Walls: R-19 (batt + sheathing)

Exterior Perimeter Below Grade: R-4 (beadboard)

The insulation level utilized in this home is typical of a well constructed home, even by 1986 standards.

Area of South Facing Glass: 15 Square Feet

Home Builder: Shelton Construction, Inc., Stillwater, Oklahoma

This is the same builder of the Stillwater home described in Profile Four.

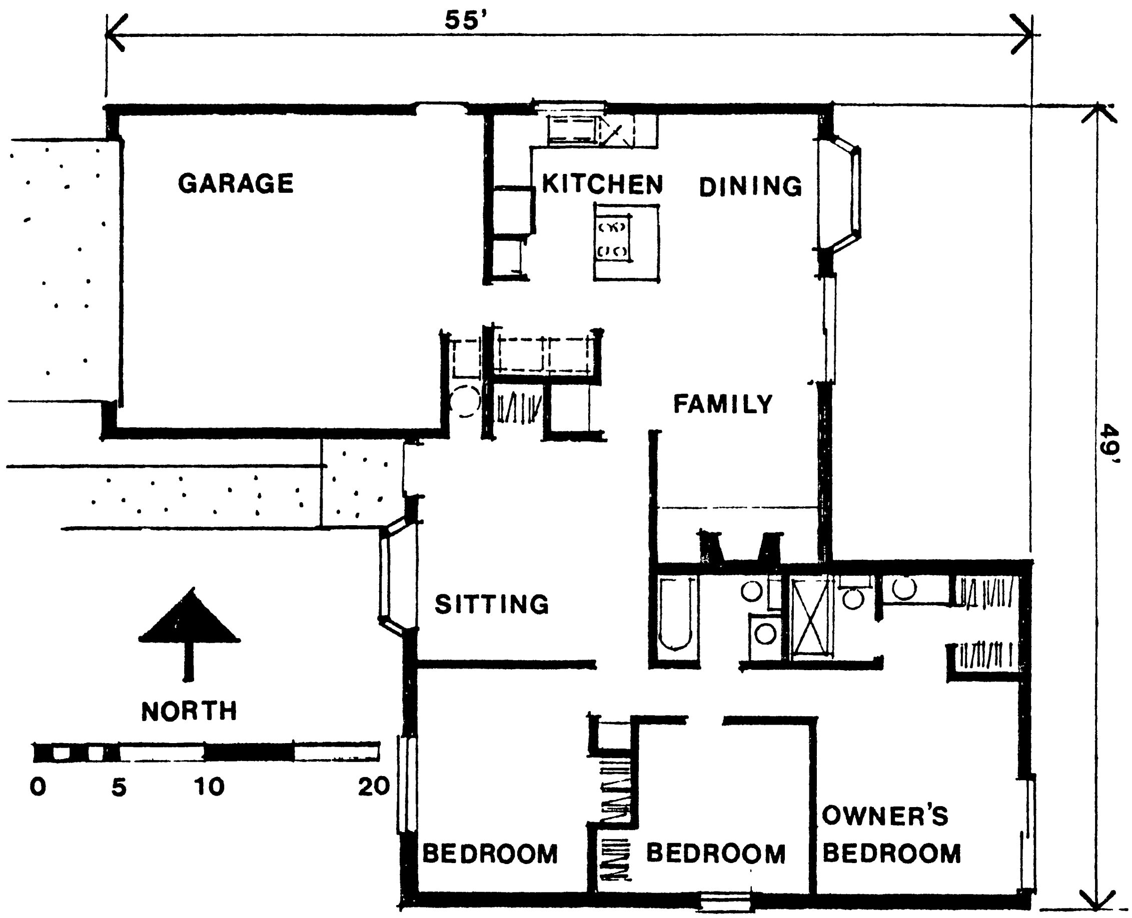

Figure 25. Conventional Home, Floor Plan

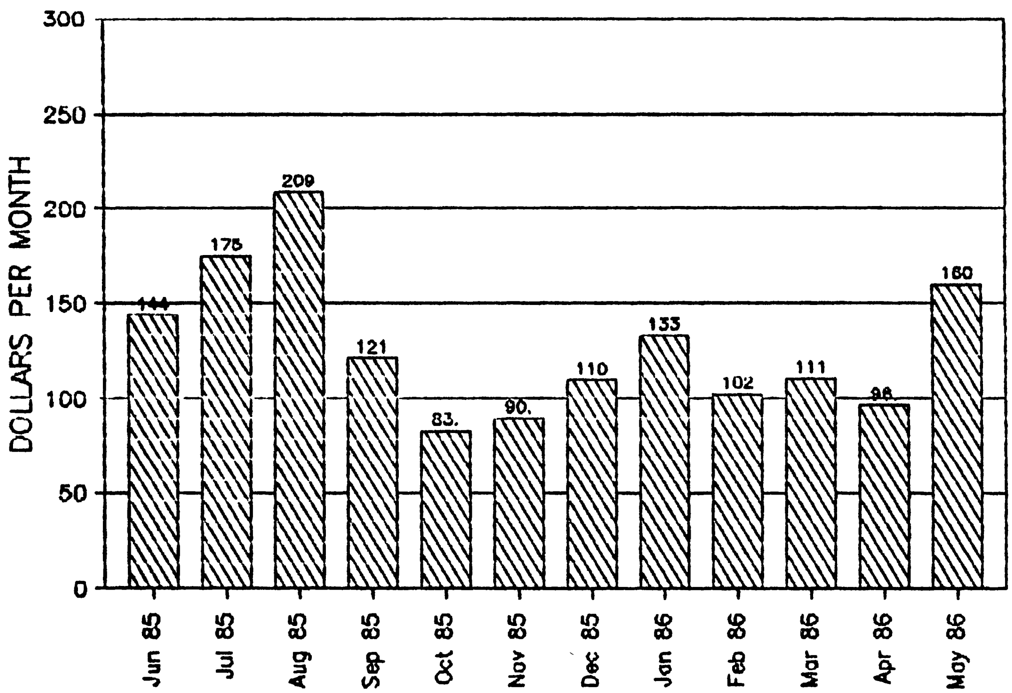

Figure 26. Conventional Home, Monthly Total Energy Costs

Profile Six

The Technology Transfer Home (see Figures 27-28)

Owner/Builder: J. C. Rogers Construction

Address: 704 E. Tower Park Drive, Stillwater, Oklahoma 74074

Date of Occupancy as a Sales Model: December, 1985

Living Area: 1350 Square Feet

Garage Area: 418 Square Feet

Sales Price: $68,000 Basic Price (includes $10,000 for land)

Actual Delivered Price averages $70,000

Cost per Square Foot (not including land): $44.44

Number of Major Rooms or Areas: Six

Auxiliary Heat Source: York natural gas fired furnace

Alternative Heat Source: Wood burning stove in living room. No outside combustion air source.

Utility Companies: Oklahoma Natural Gas; Stillwater Municipal Utility

While the home has been finished for five months, it is being used as a sales model from which 14 other homes in the development have been sold. Energy usage cannot compared with the other occupied homes on an even basis.

Insulation Levels:

Ceilings (vaulted): R-30 (flat): R-40

Exterior Walls: R-19 (batt) + R-5 (sheathing)

Perimeter Slab Insulation: R-5 (vertical), R-5 (horizontal)

Area of South Facing Glass:

Direct Gain: 87 Square Feet

South Facing Glass Divided by Living Area: 6.44%

Additional Features: Window Quilt R-5 night insulation can be pulled down over windows. Vestibules are provided for front and rear patio entrances. Air to air heat exchangers are provided so the energy in the exhausted bath and kitchen air can be exchanged with the incoming outside air.

The use of aluminum windows with a one-half inch insulating glass has been found to be entirely unsatisfactory. The aluminum windows were so poorly made and the air infiltration so excessive that the window quilt (the inside window covering) would pressurize and bow out, even when there was a light wind outside.

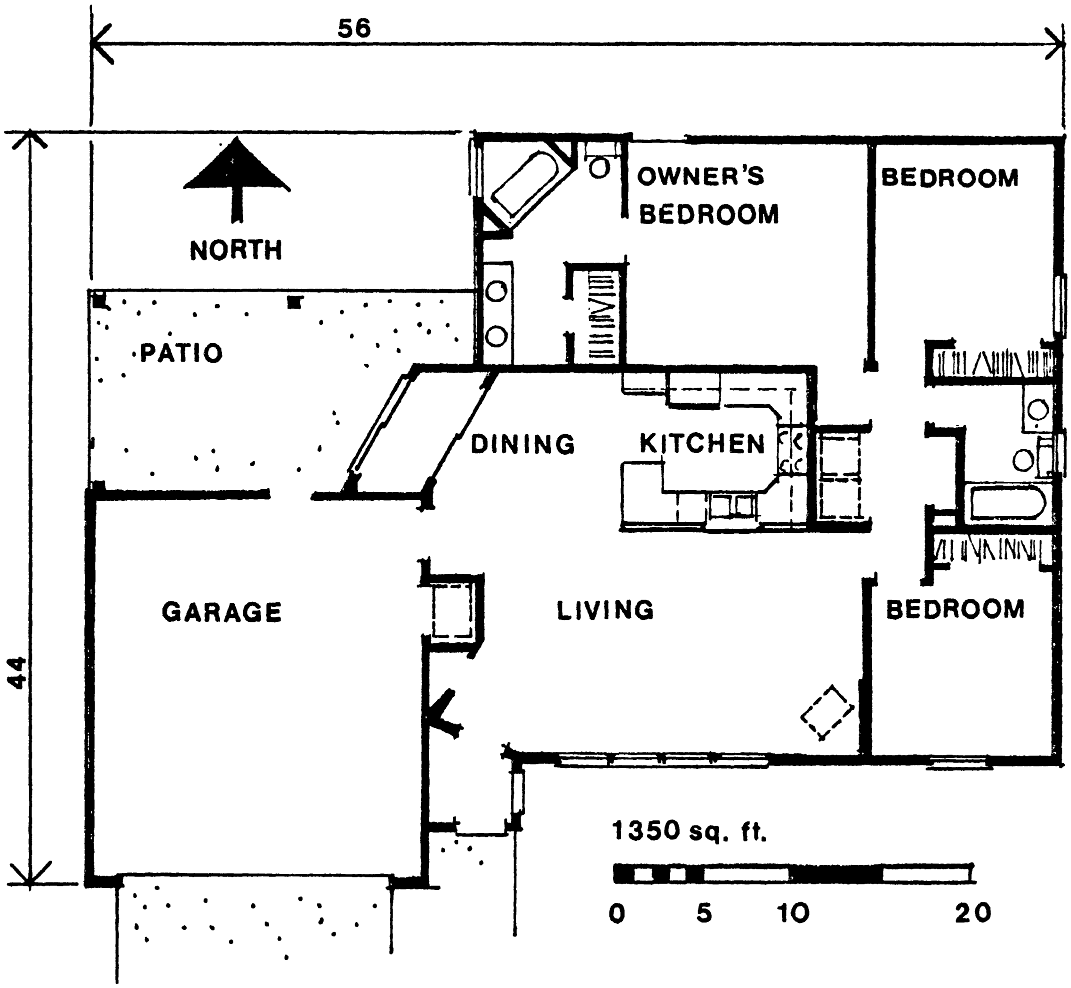

Figure 27. Technology Transfer Home, Floor Plan

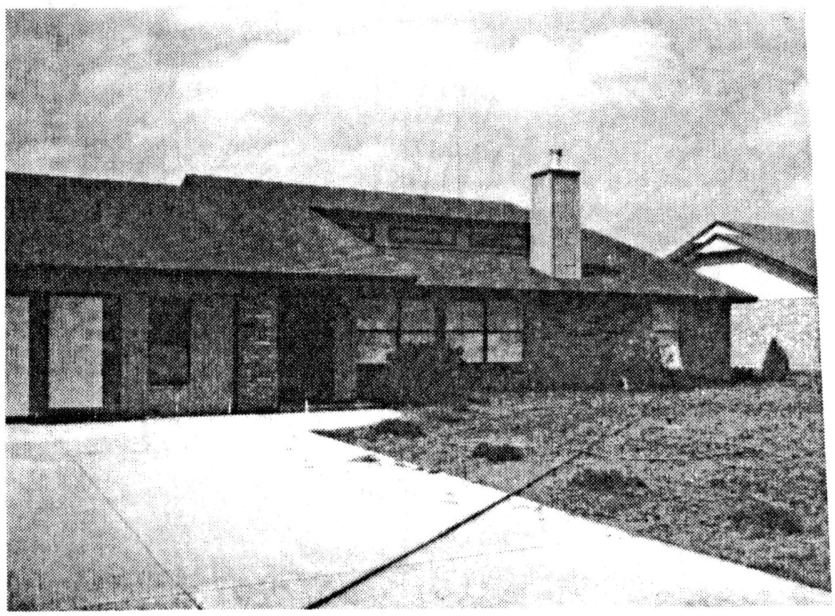

Figure 28. Technology Transfer Home, Exterior, South Side

Building Characteristics

The cost of the homes varies significantly, from \$24.04 to \$55.00 per square foot (Table I). This variability in price was affected largely by the local housing market, the degree of finish, and the participation of the owner in the contracting process. The homes shown in Profiles One through Four all used the same basic specification for construction materials; however, the owners did modify the specification occasionally when they felt the price of the process or the material specified was not to their advantage. In comparing the prices of the builder constructed "conventional" and "technology transfer" homes, a higher price for the energy efficient homes has not been established by the construction cost data collected. The omission of the berm wall in the Stillwater home would have made it comparable in cost per square foot when compared to the builder homes.

Homes shown in Profiles One through Four all used brick veneer exterior, with rough-sawn wood trim and composition roofing shingles. The homes in Profiles One through Four used "2 x 6" outside stud walls, and premium quality double pane windows with wood frames. Homes in Profiles One, Two, and Three used the same levels of insulation. The Stillwater home used the highest levels of insulation and a wood frame window that incorporated a product marketed as "heat mirror" that serves as an invisible insulation by reflecting long wave (heat) radiation back into the home. The window used in the Stillwater home creates two air spaces between the glass instead of the conventional one.

The Medford home and the Stillwater home both used a earth berm on the East, North, and West walls of the houses. The concrete wall extended to 3'0" above the main floor level. The earth berm wall required a great deal more concrete form work, wall waterproofing, and rigid insulation than were used in the Hugo and Claremore homes. The Hugo home had a three-car garage, while the others had only two-car garages. The Medford home has a partial basement and a porch; all of the other homes in the study used concrete slab on grade construction.

TABLE I

SIZE AND COST CHARACTERISTICS

	Hugo	Claremore	Medford	Stillwater	Conventional
Profile	One	Two	Three	Four	Five
Date of Occupancy	3/83	5/85	5/83	9/84	1/83
Living Area (Sq. Ft.)	3089	2502	2246	1516	1412
No. Major Rooms or Areas	8	10	7	7	6
Usual No. Occupants	2	3	4	3	3
Construction Cost per Sq. Ft.	$38.84	$29.84	$24.04	$55.00	$38.95

The Medford home was the only one of the four that did not use quarry tile floors for heat storage. The Hugo home and the Stillwater home demonstrated the highest degree of finish as more cabinet work and finish surface materials were used in the living areas. Interior walls of all of the homes were painted or papered gypsum board; no wood paneling was used. Homes in Profiles One through Four had at least one internal brick wall (Figures 6, 20, 21, and 22). The overall visual impression of all the homes was one of light and spaciousness, except for the children's bedrooms in the Medford home that seemed "closed-in." The Medford owner chose to use only one window instead of the two originally shown on the drawings.

Costs of Energy Efficient Construction

The estimated costs of the energy savings measures are presented in Table II. The estimates are the owners' perceptions of how much more it cost to construct the home, with the energy saving and passive solar features than it would to construct the same home in a conventional manner. It was apparent during the interviews that none of the owners, including the builder of the "technology transfer house" in Profile Six, kept track of the cost of construction in a manner that would allow them to calculate the extra cost of the building elements they would classify as a part of the energy efficient construction technology. For this reason, great variation and discrepancies existed when the owner's estimates were given.

The additional cost of construction listed for the Claremore home is out of line with national figures and is admittedly only an estimation. Additional costs for energy saving features usually range from five to fifteen percent of construction cost (Cook, 1984). If the Claremore home had been constructed without the $20,000 worth of energy saving expenses, the construction cost of the home would have been $22 per square foot. The owners of the Claremore home did an admirable job in building the home for the bargain price of $29.98 per square foot (see Table I).

TABLE II

HOME OWNERS' PERCEIVED ESTIMATIONS OF ADDITIONAL COST OF ENERGY CONSERVING MEASURES

	Hugo	Claremore	Medford	Stillwater	Technology
Profile	One	Two	Three	Four	Six
Estimate	0.5%-1%	27%	4%	9%-18%	7%
	($6,000 -$9,000)	($20,000)	($2,000)	($8,000- $15,000)	($4,200)

The home builders, when asked how much it cost to construct the case study homes with the energy efficient and passive solar features as compared to a conventional home, responded as shown in Table III. The home builders in the four energy efficient case study homes were not aware of all cost data, as the homes were, for the most part, owner contracted. The great variation in the estimates could be a result of the "off-the-cuff" estimates made by the builders during the interviews.

Since all of the owners of homes in Profiles One through Four were constructed before January of 1986, the owners were eligible for federal and state income tax credits for solar devices, such as the Trombe walls. Only the owner of the Stillwater home filed for an income tax credit for additional renewable energy expenditures of $8,000. The federal tax credit was $3200. The Oklahoma state tax credit was $2400; however, it will take several years to realize that savings. The income tax credits seemed to have provided little motivation to the home owners.

TABLE III

HOME BUILDERS' ESTIMATIONS OF ADDITIONAL COSTS OF ENERGY CONSERVING MEASURES

	Hugo	Claremore	Medford	Stillwater	Technology
Profile	One	Two	Three	Four	Six
Estimate	15%	20%	4%	"Not Much"	7%
	($18,000)	($15,000)	($2,000)	No Figure	($4,200)

Energy Costs for Home Operation

The energy costs of operation of the homes in the study are presented in Table IV. When evaluating the overall cost of operation of the homes in Profiles One through Five, the relationship of the size to energy cost is obvious. The largest home, the Hugo home, with 3089 square feet, has an energy bill averaging $145.10 per month. The Stillwater home, with 1516 square feet, has an energy bill of only $50.71 per month. While both homes housed the two owners and one teenager or college-aged child, the Hugo home provides accommodations for large antique pieces, large spaces for entertaining, a shop, and two living areas. As a comparison, the smaller, 1412

TABLE IV

ENERGY COST

	Hugo	Claremore	Medford	Stillwater	Conventional
Profile	One	Two	Three	Four	Five
Energy Cost Per Month	$145.10	$103.06	$89.83	$50.71	$127.36
Energy Cost Per Sq. Ft. Per Month*	$.0470	$.0412	$.0400	$.0334	$.0902
Energy Cost Per Sq. Ft. Per Year	$.5637	$.4943	$.4800	$.4014	$1.082
Mean Est. Cost Heating & Cooling Per Month	$62.01	$24.43	$14.54	$14.55	$45.64
Mean Est. Cost Heating & Cooling Per Year	$744.12	$293.19	$174.51	$174.56	$547.66
Mean Est. Cost Heating & Cooling Per Sq. Ft. Per Month**	$.0201	$.0098	$.0065	$.0096	$.0323
Mean Est. Cost Heating & Cooling Per Sq. Ft. Per Year	$.2412	$.1176	$.0780	$.1152	$.3876
BTUs Per Sq. Ft. x Degree Days (HDD+CDD)***	6.346	4.356	5.89	5.60	16.87
(HDD)	2.11	.496	.71	1.65	6.17

Note: Since only three months of heating data was available for the technology transfer home, only "Efficiency (HDD)" could be calculated, which is 7.30 BTUs/sq. ft. x HDD.

*See Figure 29
**See Figure 30
***See Figure 31

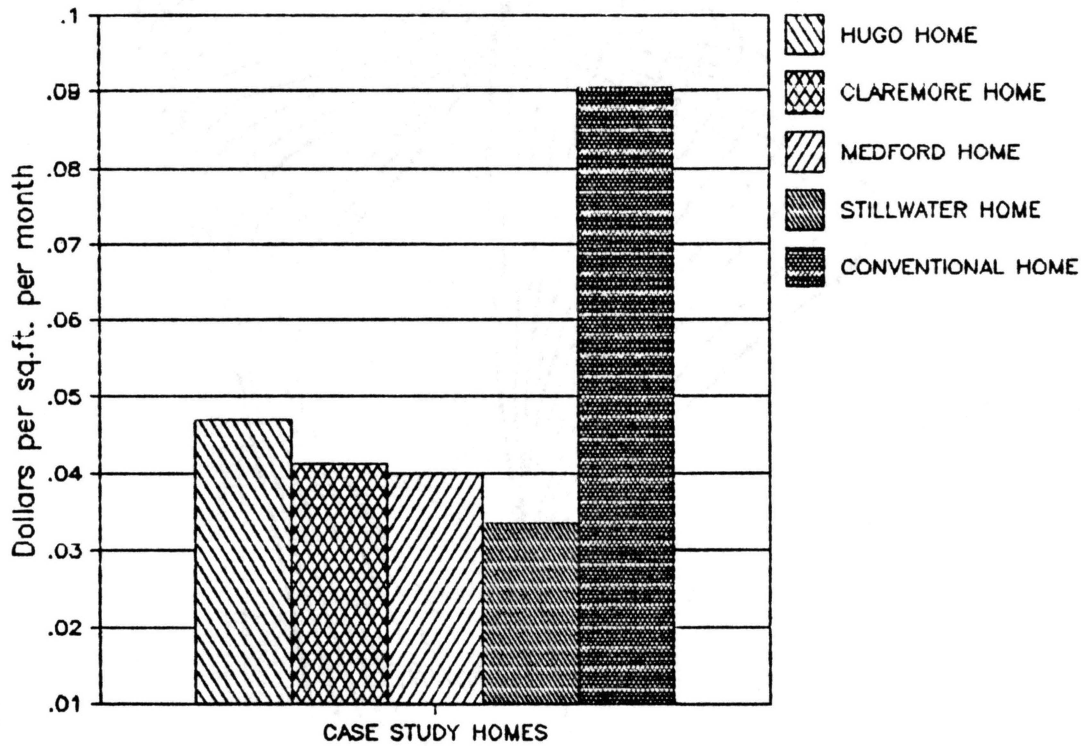

Figure 29. Mean Total Purchased Energy Costs Per Square Foot of Living Area Per Month

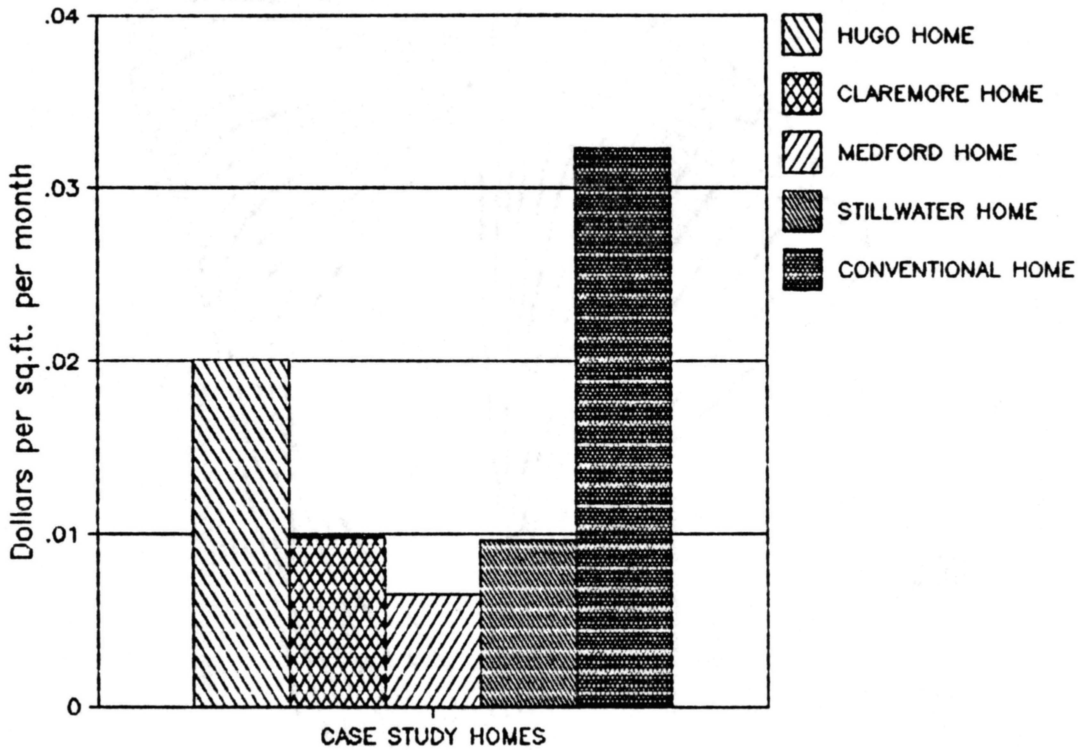

Figure 30. Approximate Mean Heating and Cooling Costs Per Square Foot of Living Area Per Month

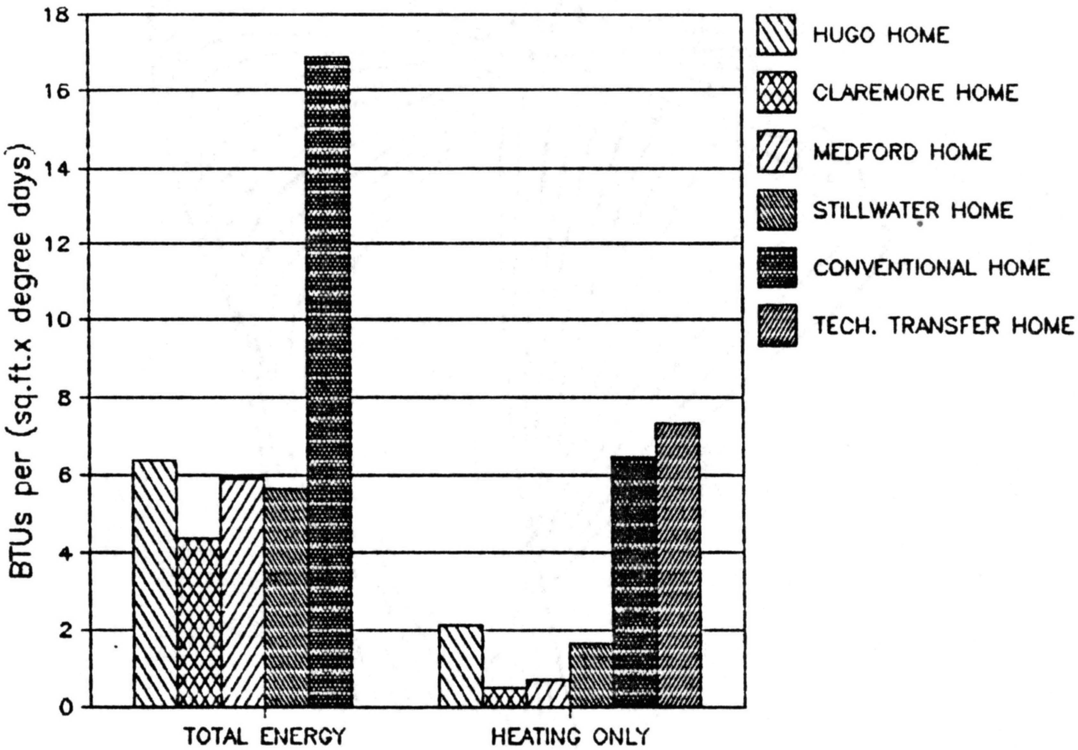

Figure 31. Adjusted Energy Use Comparison, Energy Efficiency

square foot "conventional home" shown in Profile Five had an average monthly energy bill of $127.36.

The Hugo home and the Stillwater home reflected two different lifestyles and two different auxiliary energy sources. The Hugo home and the Claremore home are all electric, while the Medford home, the Stillwater home, the "conventional home," and the home used as an example of technology transfer use natural gas furnaces and water heating devices. The Hugo energy bill for non-heating or cooling months averaged $83.09. This may seem high; however, the Hugo home has two refrigerators, a separate icemaker in the wet bar area, a freezer, and two electric water heaters. The Hugo home mechanical contractor, now out of business, insisted that a home of this size needed two separate heating and water heating systems.

Figure 29 presents comparative cost of energy per square foot of living area, equalized for the size of the space heated or cooled. Oklahoma Gas and Electric Company (OG&E) uses $.065 per square foot per month as a typical energy cost standard for an energy efficient home (Smith, 1986). The Hugo home energy cost is two-thirds of the OG&E standard, while the Stillwater home is only one-half of the $.065 standard. The "conventional home" per square foot energy cost of $.09 is nearly three times the cost of operation of the Stillwater home.

The use of electricity for lighting, cooking, clothes drying, refrigeration, and water heating is not so much a result of the design of the home, but is primarily dependent upon personal choice, number of efficiency of appliances, number of family members, and their lifestyles. To make an estimation of this personal use of electricity, the simple mean of the energy costs of the non-heating or cooling months was calculated. The utility costs for the months of April, May, and October were generally examined, in the all-electric homes, to establish utility costs not affected by climate and outdoor temperature conditions. In the homes served by a natural gas utility, the sum of six to eight of the lowest gas bills and six to eight of the lowest electric bills were averaged to calculate the mean energy cost not involving heating or cooling. The above mean was then subtracted from the mean of the total energy bill for the case study homes to arrive at the mean monthly heating and cooling expense (Figure 30).

The personal choice of electrical use was alsoinfluenced by the use of multiple refrigeration units. The rural homes (Hugo, Claremore, and Medford) had a freezer and often two refrigerators. One of the refrigerators was usually an older, less efficient model. The Stillwater home had only one high-efficiency refrigerator. The "conventional" home had only one refrigerator.

In order to compare the efficiency of homes in different climates, equalize the variance in utility rates, and equalize for size of floor area. BTUs purchased are divided by the quantity of degree days multiplied by the floor area of the space. This quotient, presented in Figure 31, is often termed the "energy efficiency." The bars of the graph on the "total" side represent the total energy purchased for heating, cooling, and operation of the home. The bars of the graph on the "heating" side represent an approximation of the BTUs used only for heating. Only heating degree days are used in the "heating" side of Figure 31, whereas the annual sum of heating and cooling degree days is used to calculate the "total" side.

The number of degree days (used in Figure 31 and presented in Figure 32) is calculated using 65 degrees Fahrenheit as a base. Heating degree days (HDD) are calculated by subtracting the mean daily temperature from 65 degrees. Cooling degree days are calculated by subtracting 65 from the mean daily temperature. The monthly sum of the degree days indication used by utility companies to forecast demand were shown in Figure 32. For the purposes of this study, a central Oklahoma setting was used.

It is an often heard complaint that all-electric homes are not economical to maintain; however, it is apparent that the fuel source is not the only problem to be faced when designing an energy efficient home. Lifestyle, orientation, window construction and installation, and many other construction considerations can ovewhelm the economics of the use of natural gas as the heat source. The conventional home operational cost indicated that even the inefficient heat pump systems installed incorrectly can be more efficient and economical than a gas furnace, in some cases. The difference between the use of natural gas and electricity for heating the space and the domestic hot water is shown if the "all electric" Hugo and Claremore homes are compared with the Medford and Stillwater homes. The cost of energy averaged 0.8/cent more per square foot per month in the all-electric homes. While 0.8/cent seems small, that difference in a year would pay for the energy bills of the Stillwater home for 2.5 months.

In examining the monthly energy use of the homes (Figures 7, 11, 15, 24, and 26). it is apparent that the Claremore home is not following the usual pattern of energy use (there does not seem to be a large difference between the heating/cooling months and the non-heating/ cooling months. Figure 32 presents heating degree days (HDD) and cooling degree days (CDD) for Oklahoma City. The amount and severity of cold days are measured by HDD. The amount and severity of hot days are measured by CDD. The pattern of the graph (Figure 32) should be reflected in energy purchases (Figure 11).

During a return trip to the Claremore home, it was verified that the heat-recovery unit installed on heat pump lines was installed incorrectly.

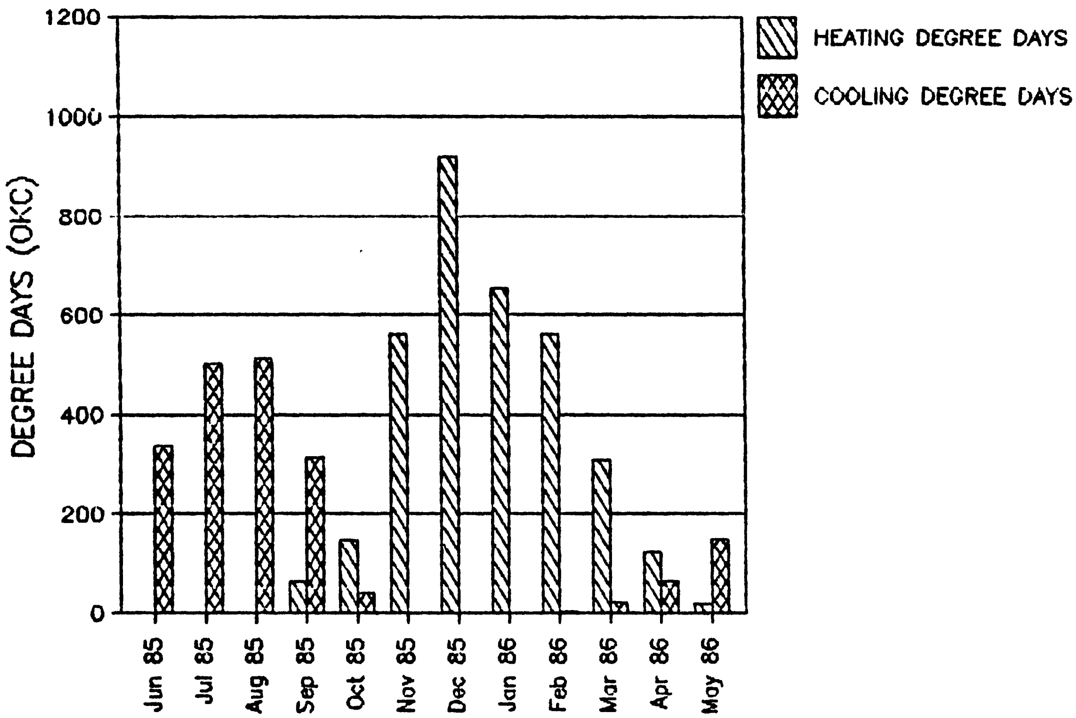

Figure 32. An Indication of Heating and Cooling Needs, Monthly Heating and/or Cooling Degree Days

The water heater robbed the heat pump of heat in the winter and put an additional heat load on the air conditioner in the summer. The device could not have been installed in a worse configuration to waste the purchased energy. The owner had also installed a loop of water pipe from the hot water tank to a wood burning stove located in the garage. The intention was for the loop of pipe to receive heat from the wood burning stove, but the loop was acting as a thermosiphon (constantly circulating the electrically heated hot water to heat up the garage and the great outdoors when the wood stove was not working). The owner did not have a fire in the wood stove after mid-January, so a large amount of heat was sted by the intended energy conservation device.

The purchased energy amounts shown in Table IV for the Claremore home do not represent the true efficiency of the home, because of the error in configuration of the piping. When the researcher explained the above installation problem to Carl Ledbetter, President of the Oklahoma Heat Pump Association, he replied, "No matter how efficient you can design a home, a mechanical system can be installed to overcome that efficiency" (Ledbetter, 1986, n. p.).

The cost of heating and cooling in the Medford home is influenced by the use of the wood burning stove to heat the home in the winter. The estimation procedure does not give a true picture for the Medford home heating costs because of the owner's dependence on the wood stove for space heating. The owner stated that the amount of wood burned is minimal and it does not pose a problem to desired lifestyle.

In all of the energy comparisons, the energy efficient homes uniformly demonstrated a cost of operation efficiency. The mechanical problems with the heat pumps in the Hugo and Claremore homes reduced the normal coefficient of performance from two and one-half to approximately one. The savings for proper performance of the heat pumps could reduce the BTUs consumed by the heating/cooling system by at least one-half.

It is unfortunate that the builders, bankers, and the utility representatives have no accurate records of the operational costs of the homes they had constructed, financed, or supplied with energy. The builders all admitted that the home building project made money for their firm, and was a financial success as far as they were concerned. None of the homes presented any financial problem to the lending institution that held the mortgage.

Window Configurations and Coverings

The percentage of south facing glass in the homes, as compared to the living area, is shown in Table V. The amount of south-facing glass can have a pronounced effect on the energy efficiency of the homes and the thermal comfort of the spaces. The south-facing glass, assuming it is double glazed, is a net energy gain in the heating season. The United States Department of Energy guidelines recommend that an Oklahoma home should be constructed with 11 percent to 22 percent of the living floor area in south-facing glass to achieve from 25 to 41 percent savings in annual heating expense (U.S. Department of Energy, 1980). If the owner selects to use an R-value of nine insulating curtain during the night, the percentage of savings on purchased heating can be 40 to 67 percent. The 6.5 percent of south-facing glass used in the technology transfer home demonstrates that the builder did not understand the significance of the south-facing glass, or was overly concerned with window costs to the detriment of the efficiency of the home.

None of the case study homes, except the technology transfer home, have incoporated the use of the night window covering with a high R-value.

The "conventional" home and the technology transfer home use one-half inch insulating glass in an aluminum window frame. The Stillwater home uses a window that has an R-value of five, with no additional window coverings. All of the other homes selected to use the usual draperies, Roman shades, or miniblinds for window coverings.

TABLE V

SOUTH-FACING GLASS

	Hugo	Claremore	Medford	Stillwater	Technology
Profile	One	Two	Three	Four	Six
Area of South-Facing Glass Sq. Ft.	385	422	343.6	274.5	87
South-Facing Glass/ Living Area	12.5%	16.9%	11.5%	18.1%	6.5%

As all of the homes have a fairly equal insulation level, the amount of savings resulting from south-facing glass depends upon the night window coverings, the percentage of south-facing glass, and the amount of mass thermal storage in the home. The builder of the technology transfer home, shown in Profile Six, admitted that the "Window Quilt," with an R-value of 5, is the most frequently accepted option of his new buyers. The owners of the energy efficient homes (Profiles One through Four), using the premium quality window (Andersen, Pella, and Hurd), have not selected to install the heavy night insulation window coverings, but have optioned for the more open spatial quality. The infiltration rate for the premium quality window is very low by itself and do not present "draft or infiltration" problems. The technology transfer home buyer has to revert to "patch up" options to compensate for the less expensive "standard builder" window. The installed quality of the wood window now being installed in the technology transfer homes will hopefully correct this weak link in the energy efficient quality of the homes. While it is not part of this study to examine window economics, it is apparent that the conventional home and the technology transfer home windows are weak points in the otherwise fairly good building envelope.

The lack of exposed mass (tile or concrete floors and interior brick walls) in the homes will cause those homes with more than 11 percent of the floor area in south-facing glass to overheat on mild winter days. The Medford home has had a mild overheating situation, as the owner omitted the tile floors and installed carpet instead. Since the south-facing glass to living area percentage is only slightly above 11 percent, the overheating would be expected to be minimal and the opening of a window could easily mitigate the problem (Table V).

The Stillwater home will overheat slightly on mild winter days when the inside temperatures reach 80 degrees without the air being circulated by the furnace fan. The Stillwater home has quarry tile floors in every room except the bedrooms. Area rugs are used in the seating areas of the living room and dining area. In addition to the glazed quarry tile floors there is a brick wall in the living room behind the wood stove and another in the sun room to be used for heat storage. The Stillwater home, having the largest percentage of south-facing glass (202.5 square feet--direct gain, 72 square feet--indirect gain in the Trombe walls) requires 815 square feet of massive material exposure to satisfy the three to one recommended minimum ratio of exposed mass to direct gain south-facing glass. The Stillwater home can be heated only by the sun on cold sunny winter days or the wood stove on cold winter nights. The "conventional home" has no significant south-facing glass, as the major glass areas on the rear of the home are oriented east; the front windows face the street to the west.

CHAPTER V

RESULTS AND DISCUSSION OF PERCEPTIONS

Comfort as a Major Benefit

One of the benefits of the energy efficient home is comfort. All of the owners of the case study homes (Profiles One through Four) stated that their homes were the most comfortable in which they have ever lived, and all considered thermal comfort an important reason for building the homes. In addition, all of the owners stated that the degree of thermal comfort came as a surprise to them after they moved into the home. The owners of the Hugo home stated that a stable inside temperature, free of rapid fluctuation, was one of the true advantages of their home and a major factor in their evaluation of thermal comfort. The owners of the Claremore home stated that they were expecting the home to be comfortable; however, they were pleasantly surprised at just how well the passive solar design worked.

The owners of the Hugo and Stillwater homes believed the tile floors to be very comfortable and warm. The Hugo home owners chose not to buy area rugs for two years after the initial occupancy, as the tile floors were comfortable and easy to maintain. The tile floors did not create a reverberating noise problem since the inside brick walls were designed with openings in the head joints of the brick to allow the sound waves to be absorbed in the soft insulation or acoustical tile installed behind the brick (Figures 6, 21, and 22). The Stillwater home owners felt the tile floor was an item of convenience and comfort, and would tile the entire home next time.

The use of the Trombe walls (Figures 4, 19 and 20) add to the thermal comfort of the occupants, as the brick walls become very warm to the touch during the winter days. The Trombe wall acts as a large radiator in the evening in the living and bedroom areas of the homes. The exterior view of the Trombe wall (Figures 4 and 19) is a dark brick wall, eight inches thick, that is glazed on the outside with one inch tempered insulating glass. The outside brick and mortar is very dark to aid in solar absorption, but the inside brick color can vary (Figure 20). The Trombe wall adds to the feeling of comfort because it is a large exterior wall that is warmer than body temperature and thus radiates warmth to the body. In the conventional and technology transfer houses the exterior walls are as much as 30 to 40 degrees cooler than body temperature during cold winter nights.

The bankers, builders, and utility representatives were asked if they had been in the subject homes after the homes were operating and occupied. Only one utility representative and one builder had been inside any of the subject homes, and those visits were not enough to make any judgment concerning the degree of thermal comfort provided by the home. Bankers typically made final check-up visits before the home was occupied. The lending institutions did not ask, nor were they told, the amount required for operating expenses in the homes. After the bankers were told of the energy costs of the subject homes, they viewed the expense involved as lower than normal or very much lower than normal. The lack of feedback and post-occupancy evaluation will be discussed in Chapter VI.

Decision Makers' Definition of an Energy Efficient Home

The definition of "energy efficient" as it applies to residential construction is a central issue to this study. All of the respondents were given the same question and asked to select and modify the definition to fit their own personal perception of how an energy efficient home should be defined. The question is shown in the Appendix.

Three utility company representatives, the builder of the technology transfer home, and one banker selected the definition having to do with total energy costs, in which a simple total dollar amount would be the gauge of energy efficiency. They selected four different criteria to be used as the measurement, as follows:

a. any utility bill for heating that is below $100/month;

b. any utility bill that is below $.05 per square foot per month;

c. any utility bill that is below the utility system average; and

d. any utility bill for heating that is below $100 per year.

All of the home builders, except the builder of the technology transfer home, selected defintion "b," having to do with the materials and insulation incorporated into the construction of the home. The builder of the Stillwater home said that the good materials must be coupled with good workmanship and careful construction methods. It is not surprising that all of the owners/contractors, with the exception of the Hugo owners, also selected definition "b," having to do with the materials used in the construction of the home. Two of the owners said that the materials definition should be modified to include the proper building orientation. Three bankers and three utility company representatives also selected the materials definition "b," of energy efficiency. One of the utility representatives commented that a high efficiency heat pump or gas furnace should be included in the definition.

The scientific definition of energy efficiency, BTUs per the product of square feet of living area multiplied by the degree days, is shown as definition "c." It was not selected by any of the respondents; however, two utility representatives admitted that it was the most accurate, but the least understood. Definition "c," or a variation of it, is used by the utility companies to forecast energy use. Definition "d," having to do with the efficiency or devices or the incorporation of solar devices in the home, was not selected by any of the respondents, except as a partial addition to the materials definition "b."

Perception of Risks in Technology Adoption

All of the persons interviewed (owners, builders, bankers, and utility representatives) agreed that the energy efficient/passive solar technolgy utilized in the construction of the homes included in the study was <u>not</u> an economic or social risk. One of the owner respondents admitted that a close relative thought they were "crazy" for wanting to build such a home, but they proceeded with the construction and the relative has "accepted" the actual constructed home. More importantly, all of the respondents would use the technology again in another home that they might build. The respondents were all very pleased with the visual appearance of the homes, and any comments from others were always positive concerning visual appearance.

The bankers closely scrutinize the location of the home, and include social risk as a matter of location within the community. The bankers will not generally make loans on earth-sheltered homes, dome homes, or log homes. The subject home owners had no problem with securing a mortgage loan because of the passive solar technology utilized in construction.

The builders of the Hugo and Claremore homes thought the construction was "a little" more complicated than a conventional home of the same size and quality. The builder of the Stillwater home saw no difference between the construction of the energy efficient home and the conventional homes he builds. Only the builder of the Medford home replied that the home was more complicated to build than a conventional home. The Medford builder was the owner, and does not build homes for a living.

Market Factors and Incentives for Technology Adoption

All of the owners said there were no energy efficient homes on the market in the areas in which they wanted to live. One of the owners said that they had owned the particular piece of land for some time and that was the overriding factor in deciding to build the subject home. All of the bankers replied that there should be more energy efficient homes on the market. The builder of the technology transfer homes was elated that his initiative to begin marketing "super-insulated passive solar homes" has met with remarkable success, even in a new subdivision.

None of the persons interviewed felt that the technology employed in the subject homes was too expensive or too complicated to use in the construction of any home. All of the persons interviewed felt that the additional cost need not be a barrier to widespread adoption of energy efficient technology.

When the builders were asked how the construciton cost of the subject home could be reduced, two of the builders listed the following:

1. use less expensive windows;

2. do not use the Trombe walls;

3. do not be so concerned about orientation, as a large quantity of fill sand was required to make the site level;

4. do not insulate the duct work under the floor; and

5. use less perimeter insulation at the stem wall.

It is apparent that these builders selected to eliminate the very items that made the homes so energy efficient.

Two of the builders said that the energy efficient home did not and should not cost any more than any custom built home of reasonable quality. The builder of the technology transfer home felt that a more reasonable sizing of mechanical equipment could reduce the cost of the energy efficient home. Mr. Rogers of Rogers Construction was concerned that the use of the Oklahoma Natural Gas "Conservator Home" sign and marketing aids might be a problem in the future if Oklahoma Natural Gas does not "police" the builders and require uniformly high materials and workmanship standards.

As pointed out earlier, the federal and state income tax credits appeared not to act as an incentive to the owners in the construction of a home. Only the Stillwater home owners filed for the tax credit, worth several thousand dollars. The Stillwater home owners' major motivation was to build a very nice, energy efficient home in an area convenient for the family. There is a great deal of personal satisfaction in accomplishing the goal that has very little to do with energy cost savings. Three of the four builders and the builder of the technology transfer home replied that they had a greater sense of accomplishment from having constructed the energy efficient home than they did when constructing a conventional home.

Energy Efficient Construction
Information Sources

The most important source of information for the home owner was the information received from the architect hired to design the home and his or her personal "experience" prior to contacting the architect. Professional magazines provided the next most important source of information. One-half of the owners did not understand the principles of passive solar design until they moved into the home and experienced the way the sun works with the building and their thermal comfort. All of the owners were surprised by the thermal comfort provided by the home. Living in the home and experiencing how it works is the best source of information.

Three out of four home builders felt that "years of experience" was their major source of information. The builder of the Claremore home had constructed over 500 homes prior to the subject home. The builder of the technology transfer home had constructed over 300 homes. Professional and trade magazines also played a major role in providing information to the builder. The other builder and the builder of the technology transfer home listed the owners' architects, visits to the Stillwater home, books, and professional meetings as sources of information. Governmental programs, OCC programs or literature, building codes, university or school-sponsored programs, or consumer and popular magazines played no role as sources of information for the builder pioneering in energy efficient residential technology. The building tradesmen, on various construction jobs, have demonstrated to the researcher a resistance to reading even a six-page building specification.

Structured educational programs from universities or vocational technical schools played no part as an information source for any of the persons interviewed, except one of the home owners and one of the utility representatives. The major source of information for the utility representatives was programs presented by the utility organization, but the utility-sponsored programs were not viewed as a source of information by the home owners or the home builders. Only two of the lending institution officers listed utility-sponsored programs as a secondary source of information on energy efficient residential technology.

One of the bankers, having been in the home and having seen a photograph of the home, and after saying that he had read articles about how passive solar design works, still asked, "Now where are the solar panels, on the roof in the back?" This remark demonstrated that he really did not understand the concept of passive solar design in housing, as there are no "collector panels," except the normal windows, and the panels certainly would not be located on the north side of the home.

Perception of the Value of Energy Conservation

All of the home owners viewed the conservation of energy as very important in home construction, as did all of the utility company representatives. Three out of the four home builders and the builder of the technology transfer home also felt that conservation of energy was very important when constructing a home. Three out of the four bankers agreed with the home owners on the importance of energy conservation in home construction. In contrast, only 30 percent of the 19 respondents felt energy conservation was as important in automobile selection. One of the respondents replied, "In both home construction and automobile selection, personal comfort was the major factor in the process of selection and deciding what to build."

Interaction of the Decision Makers

All of the home owners of the homes in Profiles One through Four perceived the utility companies to be indifferent to the fact that they were constructing an energy efficient home, and the utility representatives did not encourage the owners to use energy saving measures. There could have been mitigating circumstances for this perception, in that the Public Service Company of Oklahoma's "Good Cents" program had not begun when the Hugo home was constructed. Often, as was the case in the Medford home, the relationship with the utility company was soured by differences concerning charges for extension of service lines. The owner of the Stillwater home did not involve the gas utility until the home was nearly complete. The Stillwater municipal utility does not have any energy auditors or persons employed to aid customers in the conservation of energy. The Claremore home site had electric service for the owners' mobile home prior to the construction of the home.

Only the owners of the Medford home perceived that the lending institution officer was concerned or was encouraging about the projected saving of utility costs. The Medford home owner was already doing more of what the lending institution suggested. None of the other owners of the energy efficient homes could recall the lending institution providing any suggestions or assistance toward the owner's goal of energy efficiency.

Three out of four of the owners did think that the builders or contractors were encouraging and cooperative in making the home as energy efficient as possible. Three of the four builders said they had to instruct and remind subcontractors in the methods that were to be employed in the construction of the home. One of the builders and the builder of the technology transfer home did not employ subcontractors to do critical insulation, sealing, and window installation jobs. All of the builders thought the subcontractors were cooperative, helpful, and understanding once they understood what was desired. The builders thought the tradesmen involved learned many of the techniques of energy efficient construction technology from the experience.

All of the utility company representatives interviewed deal with the customers, usually in the role of energy auditors and customer service coordinators. When asked if the utility companies offer to teach the owners or builders of new homes how to construct the new home to be more energy efficient, the utility representatives explained the various programs, such as the "Conservator Home" program of Oklahoma Natural Gas, the "Good Cents" program of PSO, the Energy Audit programs of the Rural Electric Cooperatives, and the Audit, Peaks, and Award programs of OG&E. The PSO "Good Cents" program appeared to be the only program to aid and assist the new home owner with instruction, aid, and follow through in seeing that the home is actually constructed to save energy. All of the utility representatives who were interviewed found the builders and owners with whom they had dealings to be receptive and willing to learn techniques of energy efficient construction.

Three of the four lending institution officers interviewed said that their institutions were concerned with the energy efficiency of the homes on which they were to make loans. The institutions required homes to have minimum insulation levels and use double pane insulating glass or storm windows. The lending institutions generally see that minimum standards are included in the home plans or specifications are submitted for appraisal. The appraisal is done to establish market value and size and not energy efficiency, except as an indirect, tertiary byproduct.

Technology Transfer

If the decision makers are to learn more about the energy efficient residential construction technology, what method or source should be used to achieve the technology transfer? What would be the best informal method? The bankers stated that building codes and architectural drawings would be the best informal educational method. Home builders and utility representatives thought professional and trade magazines would be the best method, with experience and architectural drawings as the second choice.

The best formal educational method, as viewed by the utility representatives, was: (1) the utility-sponsored programs and (2) programs sponsored by universities or vocational technical schools. One builder thought the formal methods were inappropriate, while the others thought structured business or professional programs were best, with utility company programs the second best formal educational method. The bankers agreed with the builders on the best formal method (structured business or professional programs), but the bankers thought that governmental programs were the second best formal method of education.

One of the bankers and one of the builders thought utility programs would be designed to sell energy and that utility-sponsored programs would not be of any assistance. The builder of the technology transfer home thought professional organizations such as the NAHB, with its magazine and seminar programs, would be the best to educate the builders. In Oklahoma, not many of the builders outside the major cities belong to the NAHB.

It was evident in the interviews that many of the persons in business would prefer things as they are, with as little interference as possible. As Jack Shelton, the builder of the Stillwater home and the conventional home, said: "Builders like to do the things they have been doing for 20 years" (Shelton, 1986, n.p.). The bankers, who work with governmental regulation every day, were the most willing to accept building codes and government sponsored programs to achieve a goal.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Oklahoma-based utility companies are proposing the construction of as many as 20 new generating plants in the next decade ending in 1995 to meet a projected increased electrical demand (First Biennial Electric System Planning Report, 1985). Nationwide energy use for the past decade has shown remarkable savings because of conservation (Fiscal Year 1984 Annual Report of the Energy Efficient Buildings Program, 1985). Oklahoma is apparently not in step with the widespread use of effective conservation measures used in home and building design and construction. Nationwide requirements for energy conservation measures in automobiles have had remarkable success in reducing fuel demand. Oklahoma buildings have not typically utilized the available energy efficient alternatives, except added wall and ceiling insulation, to reduce energy demand and thus keep utility rates more stable.

Summary

Included in the objectives of the study were the following:

1. to provide an easily understood graphic presentation of the state of the art of energy efficient residential design;

2. to establish construction and operation benefit and cost data for the case study homes;

3. to investigate conditions and factors affecting the transfer of energy efficient residential construction technology to the builders and tradesmen; and,

4. to examine the implications of the above as it concerns utility regulation and educational programs that are concerned with the building trades.

This is a case study analysis of five homes designed by the researcher --four energy efficient homes in four different regions of Oklahoma and a conventional home in Stillwater. The conventional home was examined only with regard to construction cost and energy use analysis. One additional home was used in the study as an example of how energy efficient residential construction technology is transferred. Four major decision makers--the owner, the builder, the banker, and the utility representative--involved with the construciton of the case study homes were interviewed in 1986 concerning the home and their attitudes toward energy efficient home construction.

The cost of construction of an energy efficient home can vary a great deal. The case study subject homes varied in construction cost or price from $24 to $55 per square foot. The cost of the "conventional home" was $39; more than the cost of three out of four of the energy efficient homes. Personal choices of finish, housing market factors, and building contracting arrangements accounted for the largest differences in construction cost, even though the four energy efficient case study homes used the same building specifications. The cost of home construction in Stillwater was a significant factor in the apparent higher cost for the three Stillwater homes.

The difference between the cost of constructing the home in a conventional manner or utilizing energy efficient technology also varied a great deal. By the owners' estimations, the energy efficient construction cost from less than one percent to 27 percent more than the same home constructed in the "conventional" manner. The home builders' estimations of the differences varied from "not much" to 20 percent.

When examining the cost of operation of the energy efficient homes, the cost is greatly affected by the size of the home, the percentage of south-facing glass when compared to floor area, and fuel source. The larger the home, the larger the energy bill. The larger the south-facing glass percentage, the smaller the energy bill. The all-electric homes cost more to operate than those that use natural gas for space and water heating. When comparing a conventional home with the energy efficient homes, the cost of operation per square foot of the conventional home was two to three times more expensive. Design, materials, orientation, and lifestyle become overriding factors in cost of operation.

The cost of operation of the energy efficient home per square foot of living area per month varied from $.0334 to $.0470. The cost of operation of the "conventional" home was $.0902 for the same conditions (Figure 29). When examining the homes used in this study, the "energy efficiency" for "heating" presented in Figure 32 and the figures on the last line of Table IV are below the three BTU/(sq.ft. x DD) described by Germer (1984) as the qualifying performance of an energy efficient home.

The benefits of building, owning, or living in an energy efficient home are not just limited to reduced purchased energy costs. The sense of personal thermal comfort, with very stable indoor temperatures, also is a benefit, even though it is harder to measure in terms of dollars and cents. All of the owners of the energy efficient homes included thermal comfort as a major reason for constructing the home. The decision makers, other than the owners, had not generally been in the homes after occupancy to judge the effectiveness of the energy efficient design. There was no structured or systematic mechanism for feedback of energy cost to the decision makers.

The personal definition of "energy efficient home," as used by the decision makers involved with the construction of the home, varied from a fixed-dollar amount of energy cost to predominantly a definition that listed the amounts of insulation used, the types of windows used, the orientation of the home, and the type of energy efficient unit used for the heating and cooling of the home. The most acceptable definition to the housing decision makers of the "energy efficient home" coincided with the prescriptive (building materials) approach of the ASHRAE 90-80 standard and the NCSBCS model energy code.

The respondents saw no financial, social, or visual risk in the adoption of the passive solar/energy efficient technology employed in the construction of the homes shown and described in Profiles One through Four in Chapter IV. The respondents, who were all employing the energy efficient technology for the first time, thought the technology was only a little more complicated than the "conventional" methods used in the past. The impediments to technology adoption described by Rogers and Shoemaker (1971) were of no consequence to the respondents.

Tax credit incentives for the use of passive solar methods played little or no role in the decision of the owners to construct their homes using the passive solar technology. There were no energy efficient homes in the market area which were for sale at the time the study homes were constructed. The owners did the major share of the contracting for the energy efficient homes studied, and as such, did most of the coordination between the subcontractors and material supplies.

Builders did not receive the information necessary to construct an energy efficient home from a vocational-technical school, a university, a utility company, a government, or a business-sponsored program. No evidence was found that any of these sources played a role in providing instruction to the builders, owners, or anyone else in a decision making role concerning the methods used in energy efficient construction. Builders relied on their own experience, professional magazines, and the architectural drawings involved. There was no evidence of any common effective information source for the persons involved in the construction of the energy efficient housing.

There was little evidence of interaction between the decision makers concerning energy efficient home construction, except between the owners and builders of two of the four homes included in the case study. Owners of the energy efficient homes thought the utility company representatives were indifferent and did not encourage them to use energy saving measures when building their homes. Lending institution officers provided only minimal information on energy efficiency to the owners.

Conclusions

Based on the analyses of the data, and considering the limited number of homes included in the study, it is evident that the energy efficient technology employed in the construction of the homes in Profiles One through Four is effective in reducing operational energy costs of housing from 25 to 50 percent, in comparison to an electric utility standard of $.065 per square foot of living space per month. The savings are 48 to 63 percent when compared to a "conventional" home designed by the researcher. If all new home construction in Oklahoma were to use a similar energy efficient technology in the next decade, the growth in the demand for primary energy use and electrical power would become more in line with national trends.

The additional cost of passive solar/energy efficient residential construction technology can not be clearly established from the data collected. Interviews with the owners and builders and the cost data for the case study homes indicated that the energy efficient homes generally cost more than the same home constructed in a conventional manner. Since energy efficient homes generally have more and better quality windows, more insulation (particularly below the floor and around the perimeter), and additional interior masonry and tile floors, it is only reasonable that the energy efficient home would cost more than the conventional home. However, the conventional home in this study cost more to construct than three of the four energy efficient homes. The conventional home was constructed on a rigid budget in which the builder made the preponderance of the material and workmanship decisions, but, as would occur on many similar homes, the apparent need for two bay windows and the apparent desirability of that particular west-facing lot made other energy efficient technology choices mute. As in all types of purchases, energy efficiency is one of the choices to be weighed and considered by the consumer. Only the selection of energy efficiency can provide life of the home comfort and a chance for recovery of the investment for the long-time occupant.

The annual adjusted energy cost differential between the Stillwater home and the "conventional" home amounts to $929. Assuming a $10,000 additional cost of the energy efficient technology in the Stillwater home, and using the $4,000 income tax credit, the net construction cost increase for the Stillwater home would be $6,000. Assuming a 20-year mortgage, and if utility costs increase at a rate of 6 percent per year, the additional construction cost would be paid out with a 10 percent interest rate mortgage as the energy saving accrue, and the investment would take slightly over eight years to repay. For the remaining 12 years of the 20-year mortgage, the Stillwater home owner could save nearly $40,000, if the annual energy savings were invested with a 10 percent return.

The problem of choice between building an energy efficient home or a conventional type is clearly a question of time. It is a rerun of the old battle between life cycle costing and short turnaround on investment. The builder of the speculative house, or the owner with a very limited budget who intends to relocate in a few years, would rarely select the less obvious energy efficient options for inclusion in the home. They would probably select the "showy" options that would help sell the home quickly, or items that one could take when moving to another location. The energy efficient option provides extraordinary comfort and a sizable return on the investment over time. The energy efficient home should appeal to that market segment of home buyers who would like to "put down roots" and stay in one place. Energy efficient homes should also appeal to those with sufficient capital to make the investment in thermal comfort as a matter of choice.

Interviews with the owners pointed out that benefit cost analysis should not look only at the cost of operation and cost of construction figures, but should take into consideration the more subjective value of thermal comfort. Just as U.S. Government projects must take into consideration the subjective value of aesthetics when calculating a benefit/cost ratio, the subjective value of thermal comfort that results from closely working with the environment must be introduced into the process of housing economic analysis. While the expenditure for comfort is never questioned in the purchase of carpet, furniture, and automobiles, the expenditure for thermal comfort has become the subject of scrutiny by builders and utility companies to resist change in the way of doing business.

There was a lack of energy efficient homes on the market when the case study homes were constructed. The builder of the technology transer home believes that the marketing of energy efficient homes gives his company the competitive edge in a soft market without increasing costs to a significant degree. With only four months of unoccupied operation of the "technology transfer" home, the heating efficiency was only 7.30 BTUs/sq.ft. x HDD. Even the conventional home performed better, but the first few months of operation as a sales model is not a fair comparison. The heating efficiency of the homes constructed by the Rogers Construction Company is well below Germer's (1984) proposed performance efficiency of the "tract" homes.

The window selection, lack of internal mass, small percentage of south-facing glass, and constant use of the air-to-air heat exchanger will reduce the performance of the model technology transfer home. The initial landscaping measures of the Rogers subdivision also appeared to be in conflict with the passive solar principles of providing shade to the east and west sides of the homes, and avoiding the planting of tall conifers on the south side of the homes. It is unlikely that the energy efficiency of the technology transfer home could ever equal the efficiency of the homes presented in Profiles One through Four. The street pattern of the technology transfer home subdivision will allow future retrofit that could enhance energy performance. The transfer of energy efficient technology can not be very complete until the builders of the tract and custom homes are coerced by market pressures or regulating agencies to invest in the design and engineering measures that are the basis of energy efficient homes. The ad-hoc measures a few builders take to serve their clients will never accomplish the reduction in electrical demand necessary to forestall the future increases in utility rates to pay for the construction the proposed new electrical generating plants in Oklahoma.

The promise of energy savings shown in the energy efficient homes in the study will not be fully realized until the builders and decision makers fully understand the principles of how a building can benefit and work with the environment. While the personal interviews determined that all of the decision makers felt energy efficient housing was very important, the measure of their conviction must be demonstrated in action to change their methods of doing business, especially regarding decisions concerning energy efficiency.

The decision makers' attitudes of dominance over the environment should be changed. For example, mechanical equipment suppliers of furnaces and air conditioners feel that their job is to overcome the climate with more devices. However, their attitude should be to cooperate and take advantage of the climate and environment to do the heating and cooling job using less money and less finite natural resources. Decision makers need to adopt energy efficiency as a goal and establish a system of receiving positive and negative energy use feedback from projects constructed in the past. Only then will it be possible for the decision makers to realize the construction methods and the internal office procedures that should be changed to serve the home owner/client more effectively.

Based upon the structured interviews with the various decision makers involved with the construction of the energy efficient homes, there appeared to be no system of technology transfer for energy efficient residential construction methods. The builders, owners, and bankers have not found a coordinated, centralized, or up-to-date source for information concerning energy efficient construction. There is no structured program within the state of Oklahoma to teach housing designers, architectural students, civil engineers, landscape architects, city planners, builders, heating and cooling equipment suppliers, and other housing decision makers the methods by which housing can be made to be substantially more efficient. There is no coordinating agency and no energy policy concerning housing in the state. There are a few ad-hoc and uncoordianted efforts, such as the Oklahoma Corporation Commission Residential Conservation Service, but their efforts have had little success in reaching the Oklahoma home builder. The efforts of Oklahoma State University's School of Technology to develop procedures for the use of the earth-coupled heat pump is one example of success brought about through the cooperation of education, industry, and the regulated utilities.

The builders learn best by experience, but they develop work method inertia that resists change. Instruction and information is needed to provide a reason to change work methods. The home builders and their major subcontractors and suppliers have no guide of minimum standards or methods that could better serve the home buying customers and the community at large. While the larger Oklahoma communities do have building codes, the enforcement does not include instruction in the latest methods of energy efficiency. The code enforcement process is used as a "club" rather than a teaching device. Stillwater, for example, uses the One and Two Family Dwelling Code, a code with nationwide acceptance. The edition of the code adopted by Stillwater has been updated five times since the code adoption 11 years ago, but Stillwater continues to operate with the old version of the housing code. The standards listed in the 1975 code are woefully out of date. The city requires that carefully engineered streets and utility plans be drawn of the facilities the city will take over from the developer. However, the city does little to ensure that the generally uninformed home buying consumer receives the benefit of current technology.

While it is apparent that governmental regulation has had a tremendous effect upon the energy efficiency of the nation's transportation fleet, reduced fuel demand, coupled with relatively constant world production levels, has caused fuel prices to fall. Utility company rates for electricity and natural gas to heat and cool our homes have not fallen, as the demand is still increasing, according to OCC projections. In certain states across the northern and western U.S., energy codes, coupled with high energy prices, have reduced energy demand so that planned power plants have been delayed or even shelved permanently. There is no current ground swell of support for energy codes in Oklahoma. Even with the depressed energy and agricultural industries and reduced public payrolls, the adoption building codes (including an energy code) could provide a uniform and effective basis of new housing energy performance in Oklahoma.

Utilities train many of their own employees in certain aspects of energy efficient housing; however, those teaching efforts are not being transferred effectively to the other decision makers in the housing industry. There seems to be distrust of the sincerity of the utility companies' efforts on the part of the owners and builders involved. The Public Service Company of Oklahoma's "Good Cents" program has the potential to reach the builders and owners of new homes; however, their "pitch" is obviously slanted to the use of heat pumps, without recognition of the availability of natural gas in many areas. Natural gas is a reality in much of Oklahoma for many years to come, and it does not make economic sense to burn natural gas to generate electricity, considering the generating and distribution inefficiencies. While the use of natural gas generating plants to take care of summer peak demand makes more economic sense, it makes more sense to design our homes and landscape our neighborhoods to reduce cooling load demand.

Recommendations

The length of this study by no means represents the final word in the study of energy efficient homes. Further studies are needed in every area of Oklahoma to demonstrate the advantages and disadvantages of each type of home and energy saving technique in use. When energy performance studies are made of our homes, we begin to better understand the patterns of use and energy consumption. Further studies should be done to enable the consumers, builders, bankers, utility representatives, and those in positions of political power to understand the logic of working with the environment when designing any home or building.

While the municipal utilities are usually only a broker/agent of the investor-owned utilities, the municipal consumer does not receive the advantage of the PURPA mandated conservation assistance. Those areas such as Stillwater, which are served by municipal utilities, should be required to provide the same services, namely, energy conservation consumer assiststance required by the PURPA regulations. Investor-owned utilities and the Rural Electric Cooperatives presently have contact personnel in all areas of the state who work with builders and owners to establish new service to new structures. While some of the contact personnel may be holdovers from the energy marketing days, the utilities have an informed cadre and the most apparent opportunity to effect change in the energy efficiency of the housing stock of Oklahoma.

A move to reduce the increase in electrical demand could be made through the use of "conditions of service," utilizing standards much like the standards currently being used for the PSO "Good Cents" program and the OG& E "Award" program. The conditions of service should be mandatory for new housing and substantial additions and modifications. Conditions of service, used by many utilities, require that the customer does not waste energy, thus putting an unfair demand upon the system. The Long Island Lighting Company in New York intalls meters and makes the final connections for consumers only after the utility representative confirms that the home in question has the proper insulation levels, proper types of windows, and energy efficient appliances (furnaces, air conditioners, and water heaters). The conditions of a service program must verify the actual work, much like the "Good Cents" program presently does.

A dichotomy of cross purposes seems apparent when the utility needs to see its product make a profit, but is required to help and require the consumer to use the product efficiently. As much of the consumer's convenience and comfort is in the grip of the utility company, the consumer is skeptical of the utility's motives. The consumer feels insignificant when he or she realizes the size, resources, and monopolistic advantage of the utility. Utilities spend a great deal of money promoting a service image, but "conditions of service" regulation would have a tendency to work against the "good guy" image unless the program was carefully administered to maintain the "helping" image. The utilities need to explain to the consumer the cost of the proposed generating plants and should point out the need for effective measures to maintain reasonable utility rates.

The lending institutions, however, could have an enormous impact on the quality and energy efficiency of housing by virtue of the power of the purse. The interviews indicated that there was a more trusting relationship between the bankers, owners, and builders. Lending institutions would merely have to require the use of energy efficient residential technology materials, orientation, and methods as a condition of securing the loan. The existing minimum recommendations of insulation and storm windows would have to be replaced with an energy code or a list of requirements which included up-to-date measures that would ensure energy efficiency of the new home. This would provide a significant opportunity for the home owner to reduce his or her energy expenditures.

The borrower should understand that the advantage of compliance with the energy efficient requirements would be a reduction in the living expense allowances now calculated in the cash flow process. While the increased cost of the home would cause a modestly higher mortgage, that higher amount would be offset by the reduction in utility expenditures. Whereas utility expenditures literally "go up in smoke," savings from energy efficiency can enhance consumer choices, buying power, and a secure retirement. Energy efficient houses simply allow the owner to spend his money in the areas of comfort and accommodations rather than with the utility. The lending institution should benefit from the redirection of consumer spending.

To establish some system of feedback so the decision makers can evaluate the energy efficiency of the homes, a record of the annual energy use of a home should be maintained by the lending institution, just as with tax and insurance payments. While it is not the researcher's recommendation that the lending instituiton pay any utility bills, the lending institution should receive a copy of the annual energy use records as a part of the property appraisal. The energy efficiency of the homes should be a factor in the overall value of the property. The energy efficiency of the home does affect the owner's cash flow and thus his or her ability to maintain the property.

Builders should also be furnished with energy use records of homes for the first five years of operation. Records of energy use, or proposed energy use, should be a part of home sale documents to impress potential buyers, just as has been done with the Environmental Protection Agency gasoline performance guidelines used in the process of automobile selection. Each utility maintains at least a 12 month computer record of their accounts and could provide each home builder a printout of annual energy consumption. Builders could develop a "track record" of the energy use of the various types or models of homes so the builders and the buying public could clearly see the effects of the methods and materials utilized by the builder. Examination of performance data can be of great assistance to the home owner, as can energy audits, in discovering mistakes in installation or costly practices of usage. The "protection" of utility cost records as a matter of great personal privacy should be modified to accommodate informed and helpful examination.

The State of Oklahoma has laws that enable the various governmental agencies such as counties or municipalities to adopt building codes. However, the state has not taken an effective stand to unify and coordinate the building trades to what should be a common goal--the use of existing technology to hold down energy consumer expenses. The state should adopt a uniform building code for the state which is similar to what the states of California, New York, Wisconsin, Indiana, Virginia, North Carolina, and others have done. The uniform use of the codes will reduce confusion on the part of those involved in the building trades. Certainly, several codes will have to be utilized to cover all aspects of building, but the same group of codes should be utilized and administered across the state. The current One and Two Family Dwelling Code was developed cooperatively by the three major building code groups as a consensus code that serves as a guide for the small scale builder. The current One and Two Family Dwelling Code, with its Energy Code appendix, should be adopted by the Oklahoma Legislature as the code for all home construction across the state.

The building code could be administered by either the State or County Departments of Health in the areas of the state that do not presently have any building officials. County Health Department sanitarians currently must inspect septic and well installations for each home not within a municipal system. A requirement that the builders certify and file the plans with the county/state official would at least get the conscientious builder to study the code and follow its procedures. If that certification was also required by the lending institutions as a condition of receipt of the loan, the builders would see an even more persuasive reason to comply with the code.

Since the construction of housing is as important as the driving of an automobile, the building permit procedures could be expanded to keep the builders current with technological advances in housing construction. Just as the drivers read a booklet and take an examination, the builders and tradesmen could be required to take continuing education courses and even a short test as a condition of the granting of a building permit. The continuing education programs and building permit examinations should be administered as the means to educate and maintain standards that are in the public interest.

Even though Oklahoma has two architectural schools, very little of the curriculum is oriented towards housing energy efficiency. The importance of design for climate and energy efficiency could be incorporated as an easily recognizable part of the curriculum. Although the design professions are not involved in much of the new housing that is constructed across the state, home planning services and the design professions should respond to the energy code requirements or the requirements of utilities and lending institutions. This could help provide building sites and building plans that are in concert with the overall goal of reasonable living costs within a clean environment. The largest share of Oklahoma housing is designed, as well as constructed, by the realty and building professions. The builders, realtors, and other trades need to learn and understand the concept of energy efficient housing and the economic importance of working with the environment.

The Oklahoma Chapter of the American Institute of Architects is mounting a campaign to make the typical Oklahoman aware of the value of design. The reasons for energy efficient residential design and construction should provide a viable and clearly understandable logic as to why the Oklahoma home owner and home builder should utilize the design professions to save money and to preserve our environment. The design professions (engineers, architects, landscape architects, and interior designers) should also be part of the continuing education effort within their professional groups, and, more importantly, as the consultants and assistants to the housing decision makers.

The state's educational institutions need to coordinate their efforts to provide a means of formal seminars or classes to train the tradesmen that serve our communities. Building code adaptation, or even requirements for builder continuing education, would provide a ready audience for the instructional programs of our vocational-technical schools, universities, and colleges. The building trade and technical schools should adopt a goal to educate technicians and tradesmen in the overall picture of how a home works within the environment. Just as general education requirements are set for the college student, the housing decision makers and technicians should be able to understand the "ecosystem" of a house, the occupants, and the climate.

The materials, the assembly configuration methods, and their critical home operation factors of energy efficient housing are too important to the future well-being of the state of Oklahoma to be allowed to "fall through the cracks" in our extensive educational system. There seems to be no teaching of energy efficient home design and construction technology to the housing decision makers in any meaningful way. Since vocational-technical schools are located in every area of the state and are working with persons in all trades and professions, they have an excellent opportunity to intercede and fill the apparent void in the education of an important segment of the population.

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APPENDIX

HOME OWNER QUESTIONNAIRE

Your name will not be used in the report unless you specifically grant permission ....

A. Home Owner's Name

B. Home Location

C. Living Area of the Home

(including outside walls, but not including unheated spaces)

D. Area of south facing glass

direct gain

indirect gain

E. Date of first Occupancy

F. Lending Agency Utilized

G. Utility Company..natural gas

electricity

other

H. Building Contractor or Home Builder

1. There seems to be some confusion as to the definition of "energy efficient" as it is used to describe how well a house is constructed. Which of the following definitions more closely coincides with your personal definition of "energy efficient"? Please check the appropriate blank. If your definition varies somewhat from the given definition, please write in your definition in the "variation" blank given.

0 a. DOLLAR AMOUNTS OF UTILITY BILLS FOR OPERATIONAL COST

A home would be "energy efficient" if the total dollar amount of utility bills was below $ ______.

An alternative would be the dollar amount of the utility bills as compared to the size of the home, i.e. $ per square foot of living area

** If you checked the "a" blank please fill in a dollar amount in the blanks given.

Variation on a.

3 b. AMOUNTS OF INSULATION AND CONSTRUCTION MATERIAL QUALITY

A home would be "energy efficient" if the home has the which of the following materials: check the items are appropriate for your definition.

- 3 R-38 ceiling insulation,
- 3 2 x 6 exterior wall studs with R-19 insulation
- 3 R-15 perimeter insulation below the floor around the outside perimeter of the living space (stem wall insulation or floor insulation).
- 3 Has double (thermo-pane) or storm windows

_3_ Has thermo-break aluminum or wood window frames
_2_ Other ___ Orientation ______________________
(Please list)
Variation on b.2 Efficient heat source/ stove & furnace

c. QUANTITY OF AUXILIARY HEAT REQUIRED (NATURAL GAS, ELECTRICITY, OR ETC.) USED, AS COMPARED TO THE COOLING OR HEATING LOAD CAUSED BY THE WEATHER
A home would be "energy efficient" if it used less than ___ (quantity) British Thermal Units of electricity or natural gas for every heating and cooling degree day, i.e. BTU per square foot per heating or cooling degree day.
Variation on c. ______________________

d. EFFICIENCY OF HEATING OR COOLING DEVICES USED IN THE HOME
A home would be "energy efficient" if the home used which of the following methods or devices to heat and / or cool the house:
___ Electric resistance heat (the home gets to use 100% of the kilowatts purchased in heat)
___ Electric heat pump with a Coefficient of performance above ___ (state the amount, ex. 2.5)
___ A wood burning stove
___ A ground loop (water to air) heat pump
___ A heat pump for heating domestic hot water
___ Active solar panels and system to heat the space or domestic hot water
___ Other ______________________

_1_ e. Other-- "thermal comfort consistancy and temperature stability

2a. What was your major source of information on energy efficient residential prior to the construction of your home? (rank the first 3 in order using 1,2, and 3 in the blank. Number 1 is the most important.)

3rd-1	2nd-1	a.	Consumer / popular magazines
3rd-1	2nd-1	b.	Professional or trade magazines
0		c.	Utility company programs
1st-1		d.	University or school sponsored programs
3rd-1		e.	Structured Business or professional programs (Architectural, Builder, Suppliers)
0		f.	Governmental programs (Example: Corporation Commission)
0		g.	Building Codes
		h.	Other 1st-2 Architect. 2nd-1 Architect 2nd-1 trip to Architect's other homes

3. Have you applied for Income Tax credits for any passive or active solar feature in your home?
Yes _1_
No _3_ (1 thought they might apply)

If yes, please state the amount. ____

If yes, Did the tax credit provide a major incentive to the adoption of passive solar construction?

Yes

No 1

4a. Did you find many energy efficient houses on the market when you decided to buy or build a home?

Yes

No 4

4b. If No to question 4a, was the lack of energy efficient homes on the market a major consideration in deciding to build?

Yes 3

No 1

5a. Is your new home more thermally comfortable than any of your previous homes?

Yes 4

No ____

If Yes to question 5a, answer the following questions:

5b. Did you consider thermal comfort an important reason for building or buying your energy efficient home?

Yes 4

No

5c. Did the thermal comfort of your new home come as a surprise to you after you moved into the home?

Yes 4

No

6a. Did you understand before you moved into the home, how the passive solar aspects of the design of your home could allow the sun to contribute significantly to the heating of your home in winter?

Yes 3

No 1

6b. Do you understand it now?

Yes 4

No

6c. If yes to either 6a or 6b, which of the following significantly contributed to that understanding?

0 a. Consumer / popular magazines

3rd-1 b. Professional or trade magazines

0 c. utility company programs

1st-1 d. University or school sponsored programs

0 e. Business or professional programs (Architectural, Builder, Suppliers)

f. Governmental programs (Example: Corporation Comm.)
1st-2 2nd-1 3rd-1 g. Living in the home
h. Other 2nd-2 Architect 1st-1 Architect ____________

7a. Did you understand before you moved into the home, how the passive solar aspects of the design of your home could protect your home from significant summer heat gain and thus help to reduce your air conditioning expenses?
Yes 2______
No 2______

7b. Do you understand it now?
Yes 4______
No ______

7c. Which of the following significantly contributed to that understanding? (rank the first 3 in order using 1,2, and 3 in the blank. Number 1 is the most important.)
0 ____ a. Consumer / popular magazines
3rd-1 ____ b. Professional or trade magazines
0 ____ c. utility company programs
1st-1 d. University or school sponsored programs
____ e. Business or professional programs (Architectural, Builder, Suppliers)
f. Governmental programs (Ex. Corporation Comm.
1st-3 3rd-1 g. Living in the home
h. Other 2nd-3 Architect ____________

8a. Are you satisfied with the costs of heating and cooling your home? Check the one that most closely describes your satisfaction level.
2.5 very satisfied (.5 for heating only)
1 moderately satisfied (trouble w/heat pump cited)
.5 satisfied (.5 for cooling only)
____ moderately dissatisfied
____ dissatisfied

8b. On what basis do you establish your satisfaction level?
2 a. Comparison with the utility bills of former homes you have lived in.
3 b. Comparison with Utility bills of friends or neighbors
1 c. Expectations of what you thought the utility bills would be for this home.
1 d. Other Comfort ____________

9. Considering the costs and benefits of the energy efficient technology employed in the construction of your home, do you consider the technology any of the following:
a. too difficult to be employed in any homes other than custom built homes
Yes ____ No 4
b. too expensive to be employed in any homes except

custom built homes
Yes   No 4

c. enough of an advantage to construct other homes you might be building to use the same technology.
Yes 4   No

d. The use of the technology is too much of an economic risk to use again in the construction of another home.
Yes   No 4

10. Are you and are others satisfied with the exterior appearance of your home? Check the one that most closely describes your satisfaction level.

You		Others	
4	very satisfied	4*	very satisfied
	moderately satisfied		moderately satisfied
	satisfied		satisfied
	moderately dissatisfied		moderately dissatisfied
	dissatisfied		dissatisfied
	no comment		no comment
		*1	surprised as to size

11. Do you view the construction of your passive solar / energy efficient home a visual success?
Yes 4   No

12. Do you get a certain amount of satisfaction from comparing energy or utility bills with friends and / or neighbors.
Yes 2   No 2

13. Do you view building a passive solar / energy efficient home to be any more/less complicated than the building of a conventional home?

	More	Less	The Same
Construction	4		
Financing		1	3
Dealing with the Utility Co.			4
Insurance		1	

14. Do you see any social risk in building a home such as yours, i.e. using passive solar or energy efficient construction technology?
Yes   No 3   1 (a little, but went ahead)

15. Do you consider the conservation of energy important? Check the blank next to the words that best describe your level of importance.

In Home Construction	In Automobile Selection
4 very important	2 very important
__ moderately important	2 moderately important
__ important	__ important
__ moderately unimportant	__ moderately unimportant
__ not important at all	__ not important at all

16. What was the construction cost of the home not including land, furnishings (wallpaper, area rugs), furniture financing, and legal expenses ? ______

17. How much more did it cost to construct this home with energy efficient and passive solar features than it would have to build the same home in a conventional manner?

______

(examples would be additional insulation, solar equipment, trombe walls, high efficiency equipment, additional windows

18. Do you think that the additional cost of energy efficient / passive solar technology in residential construction is low enough that it should not present a financial barrier to wide spread trial and usage?
Yes 2 (perhaps some)
No 2

19. Do you think the Lending Institution Officer who handled your home construction loan or mortgage was concerned and encouraging about the projected amount of the homes utility bills or if the home was to be energy efficient?
Yes 1 (but it didn't mean anything)
No 1
Indifferent 2

20. Do you think the Utility Company representative you spoke with to receive utility service was concerned if your new home was energy efficient? (Did they encourage you to use energy saving measures?)
Yes
No
Indifferent 4

21. Was your home builder / contractor cooperative, encouraging, and understanding concerning your plans to build an energy efficient home rather than a more conventional home?
Yes 2 + .5(some)
No 1 + .5(some)
Indifferent

I hereby authorize the use of my name and / or the name of my company in the written study.

To whom it may concern,

This letter is to introduce you to Ken Larson, the architect of our the residence in which we presently live. He is working on a study at Oklahoma State University on the costs and benefits of energy efficient construction technology and the transfer of energy efficient construction technology to the decision makers involved. We have reviewed the questionnaires involved and would ask your cooperation in the completion of the study. Please provide him with the information needed to complete the questionnaires.

Thank You,

____

(Home Owner)

HOME BUILDER QUESTIONNAIRE

Your name will not be used unless you specifically grant written permission .....

A. Owner of the Energy Efficient Home under Consideration

____

B. Home Location ______________________________

C.Building Contractor or Home Builder

____

****

1. There seems to be some confusion as to the definition of "energy efficient" as it is used describing how well a home is constructed. The basis of several different definitions are shown below, which one more closely coincides with <u>your personal definition</u> of " energy efficient"? Please check the appropriate blank. If your definition varies somewhat from the given definition please write in the your definition in "variation" blank given.

_1 a. DOLLAR AMOUNTS OF UTILITY BILLS FOR OPERATIONAL COST
A home would be "energy efficient" if the total dollar amount of utility bill was below $____ per month. An alternative would be the dollar amount of the utility bills as compared to the size of the living area of the home, i.e. $____ per square foot of living area. ** If you checked the "a" blank please fill in a dollar amount in the $ blanks given.

Variation on a. ______________________________

_4_ b. AMOUNTS OF INSULATION AND CONSTRUCTION MATERIAL
A home would be "energy efficient" if the home has which of the following materials: check the appropriate
items.

_4_ R-38 ceiling insulation
_4_ 2 x 6 exterior wall studs with R-19 insulation
_2_ R-15 perimeter (stem wall) insulation or floor insulation
_4_ insulating (double or thermo-pane) glass or storm windows
____ Other "good workmanship", "rientation"

Variation on b. ______________________________

__ c. QUANTITY OF AUXILIARY HEAT REQUIRED (NATURAL GAS, ELECTRICITY, OR ETC.) USED AS COMPARED TO THE COOLING OR HEATING LOAD CAUSED BY THE CLIMATE
A home would be "energy efficient" if the home used less than ____ (quantity) of British Thermal Units of

electricity or natural gas for every heating and cooling degree day per square foot of living area.
Variation on c. ____

___d. EFFICIENCY OF HEATING OR COOLING DEVICES USED IN THE HOME
A home would be "energy efficient" if the home used which of the following methods or devices to heat and or cool the house:
___ Electric resistance heat where the home gets 100% of the kilowatts purchased in heat
___ Electric heat pump with a Coefficient of Performance (COP) of ___ (amount).
___ A high efficiency natural gas furnace
___ A wood burning stove
___ A heat pump for domestic hot water
___ Active solar collector panels and system to heat the living space or domestic hot water
___ Other
Variation on d. ____

2a. What was your major source of information on energy efficient residential construction prior to the construction of this home under consideration? Rank the first 3 in order using 1,2, and 3 in the blank.)
___ a. Consumer / popular magazines
2nd-2 3rd-1 b. Professional or trade magazines
___ c. Utility company programs
0 ___ d. University or school sponsored programs
3rd-1 ___ e. Structured Business / professional programs (Ex.NAHB, Architectural, Suppliers)
3rd-1 ___ f. Governmental programs (Ex. Corporation Comm., U.S. Department of Energy)
___ g. Building Codes
1st-3 ___ h.Other Experience 1st-1 Architect___

2b. Did you understand before you constructed the subject home, how the passive solar aspects of the design of the home could allow the sun to contribute significantly to the heating of the home during the winter?
Yes 2
No 2

2c. Do you understand it now?
Yes 4
No ___

2d. If yes to 2b or 2c, which of the following significantly contributed to that understanding? (rank the first 3 in order using 1,2, and 3 in the blank.)
___ a. Consumer / popular magazines
2nd-2 3rd-1 b. Professional or trade magazines

______ c. Utility company programs
______ d. University or school sponsored programs
3rd-1___ e. Structured Business or professional programs
______ f. Governmental programs
______ g. Building Code
1st-2 2nd-2 3rd-1_ h. Architectural Drawings
1st-2___ i. Other Experience ____________________

3a. Did you understand before you constructed the home how the passive solar aspects of the design could protect the home from significant summer heat gain and thus help reduce the air conditioning expense?
Yes 2 No 2

3b. Do you understand it now?
Yes 4
No ___

3c. If yes to 3a or 3b, which of the following significantly contributed to that understanding? (rank the first 3 in order using 1,2, and 3 in the blank.)
___ a. Consumer / popular magazines
___ b. Professional or trade magazines
___ c. Utility company programs
___ d. University or school sponsored programs
___ e. Structured Business or professional programs
___ f. Governmental programs
___ g. Building Code
___ h. Architectural Drawings
___ i. Other__"same as 2d above"________________
(please list)

4. Have you or your company ever constructed an energy efficient home before constructing the subject home?
Yes 2
No 2

If yes to question 4, How many energy efficient homes have you or your company constructed prior to the construction of the subject home? _____ (insert the number in the blank)

5a. Have you been in the subject home after it was occupied and operating?
Yes 2
No 2

5b. If yes to question 5a, Are you able to judge the thermal comfort of the home?
Yes 2 (1 is a builder/owner)
No 2
5c. If yes to the above question, how would you best describe the thermal comfort of the subject home when

compared to other homes you have constructed?
___ significantly more comfortable
_1_ more comfortable
_1_ about the same
___ less comfortable
___ significantly less comfortable

6. Are you aware of the cost of heating and cooling of the subject home?
Yes 1 (also the owner) No _3_

7. Considering the costs and benefits of the energy efficient construction technology employed in the construction of the subject home, do you consider the technology any of the following:
a. too difficult to be employed in any homes other than custom built homes Yes No 4
b. too expensive to be employed in any homes other than custom built homes Yes No 4
c. enough of an advantage to use in the construction of other homes you are considering to build Yes 4 No
d. The technology is too much of an economic risk to use in the construction of another home Yes___ No _4_

8. Are you and others you know satisfied with the exterior appearance of the subject home? Check the one that most closely describes the satisfaction level involved.

You	Others
___ no comment	___ no comment
_3_ very satisfied	_3_ very satisfied
_1_ moderately satisfied	_1_ moderately satisfied
___ moderately dissatisfied	___ moderately dissatisfied
___ dissatisfied	___ dissatisfied

9. Do you view the construction of the passive solar/ energy efficient home a visual success?
Yes _4_ No ___

10. Do you view the construction of the passive solar / energy efficient home a financial success for the builder?
Yes 4 No

11. Do you view the building of a passive solar / energy efficient home to be any more or less complicated than the building of a conventional home?

	More	Less	The Same
Construction	1		3
Financing	1		
Dealing with the Utility Co.			2
Dealing with sub-contractors	2		2

12. Do you have any more of a feeling of satisfaction or accomplishment from having constructed this energy efficient home as opposed to a conventional home.
Yes 3
No 1

13. Do you consider the conservation of energy important?

In home construction		In automobile selection	
3	very important		very important
1	moderately important	3	moderately important
	important		important
	moderately unimportant		moderately unimportant
	not important at all	1	not important at all

14a. Did it cost much more to construct this home with energy efficient and passive solar features than it would have to build the same home in a conventional manner?
Yes 2 No 1 Not a lot 1

14b. If, yes, to the above question, how much more did it cost to construct the subject home versus the same home in a conventional manner?

(examples of extra expense would be additional insulation, solar equipment, Trombe walls, high efficiency equipment, additional or higher quality windows)

15a. Do you feel that there are ways to make energy efficient or passive solar technology less expensive than the methods used in the subject home?
Yes 2
No 2

15b. If yes to the above question, please list some of the major ways you feel energy efficient / passive solar technology could be more cost effective.

16. Do you think that the additional cost of energy efficient or passive solar technology in residential construction is low enough that it should not present a financial barrier to wide spread trial and usage?
Yes 4
No

17a. Did you secure construction financing from any lending institution for this project?
Yes 1 No
3 the method of payment was done in such a way that interim construction financing was not required by the builder / contractor

17b. If yes to the above question, was the Lending Institution Officer who handled your construction loan concerned if the home you were constructing was an energy efficient home?
Yes
No 1
Indifferent

17c. Did you or the Lending Institution Officer view the energy efficiency or passive solar aspects of the subject home as any financial risk?

You or your company	Lending institution officer
Yes ____	Yes ____
No 1	No 1
Indifferent ____	Indifferent ____

18a. Did you have any dealing with the Utility Company representative in order to coordinate or secure utility service for the subject home?
Yes 1
No ____

18b. If yes to the above question, was the utility company representative concerned if the home you were constructing was energy efficient?
Yes 1
No
Indifferent ____

18c. If yes to the the above question, did the utility company representative offer any suggestions, instruction, or inspection in order to aid you in the energy efficiency of the subject home?
Yes
No 1

19a. Did you have to instruct or remind your sub-contractors in the methods that were to be employed in the construction of this energy efficient / passive solar home?
Yes 2
No 2

19b. Were your sub-contractors cooperative, helpful, and understanding of your efforts to make the subject home energy efficient?
Yes 3
No
Indifferent ____

20a. Do you view the home construction tradesmen as having learned something about the techniques of energy efficient residential construction sufficient from having been

involved in the construction of the subject home.
Yes 4
No

20b. If yes to the above question, do you think you, your company or the tradesmen involved learned sufficient techniques to be carried over into the construction of other home, i.e. was there technology transfer?
Yes 4
No ____

21. If energy efficient / passive solar construction technology is to be learned by the construction trades, through what organization or method should be used to achieve the technology transfer? (rank the first 3 in order in each category using 1,2, and 3 in the blank.)

Informal
2nd-1 ___ a. Consumer / popular magazines
1st-2 ___ b. Professional or trade magazines
______ c. Building Code
2nd-1 3rd-1 d. Architectural Drawings
1st-1 2nd-1 e. Other experience ______

Formal
1st-1 3rd-2 f. Utility company programs
2nd-3 ____ g. University or Vo-Tech school programs
1st-2 ____ h. Structured Business / professional programs (Ex. National Association of Home Builders)
______ i. Governmental programs (Ex. Oklahoma Corporation Commission)
1 ____ j. Other "none" ______
(please list)

I hereby authorize the use of my name and / or the name of my company in, or in connection with, the written study.
______

UTILITY COMPANY QUESTIONNAIRE

Your name or your company's name will not be used in the report unless you specifically grant permission...

A. Owner of subject energy efficient home

____

B. Home Location ______________________________

C. Utility Company Name ______________________
Service provided (gas, electric or propane) ______
Date of initial service (not including construction service) ______________________________
Service Representative's name ________________

****

1. There seems to be some confusion as to the definition of "energy efficient" as it is used describing how well a home is constructed. The basis of several different definitions are shown below, which one more closely coincides with your personal definition of " energy efficient"? Please check the appropriate blank. If your definition varies somewhat from the given definition please write in the your definition in "variation" blank given.

3 a. DOLLAR AMOUNTS OF UTILITY BILLS FOR OPERATIONAL COST
A home would be "energy efficient" if the total dollar amount of utility bill was below $_100_(2) per month. An alternative would be the dollar amount of the utility bills as compared to the size of the living area of the home, i.e. $_.05_ per square foot of living area. If you checked the "a" blank please fill in a dollar amount in the $ blanks given.
Variation on a. ______________________________

_2 _b. AMOUNTS OF INSULATION AND CONSTRUCTION MATERIAL
A home would be "energy efficient" if the home has which of the following materials: check the appropriate items.
_2_R-38 ceiling insulation
_2_2 x 6 exterior wall studs with R-19 insulation
3_R-15 perimeter (stem wall) insulation or floor insulation
1 insulating (double or thermo-pane) glass or storm windows
3 Other _(high efficiency heat source) ______
Variation on b.

2 c. QUANTITY OF AUXILIARY HEAT REQUIRED (NATURAL GAS, ELECTRICITY, OR ETC.) USED AS COMPARED TO THE COOLING OR HEATING LOAD CAUSED BY THE CLIMATE
A home would be "energy efficient" if the home used

less than __?__(quantity) of British Thermal Units of electricity or natural gas for every heating and cooling degree day per square foot of living area.
Variation on c. ____"Too complicated"________

___d. EFFICIENCY OF HEATING OR COOLING DEVICES USED IN THE HOME
A home would be "energy efficient" if the home used which of the following methods or devices to heat and or cool the house:
- __ Electric resistance heat where the home gets 100% of the kilowatts purchased in heat
- Electric heat pump with a Coefficient of Performance (COP) of __ (amount).
- __ A high efficiency natural gas furnace
- __ A wood burning stove
- __ A heat pump for domestic hot water
- Active solar collector panels and system to heat the living space or domestic hot water
- __ Other ____________________
  (Please list)

Variation on d. ____________________

2a. What was your major source of information on energy efficient residential construction prior to the construction of this home under study? Rank the first 3 in order using 1,2, and 3 in the blank.)

________a. Consumer / popular magazines
2nd-3____ b. Professional or trade magazines
1st-3____ c. Utility company programs
2nd-1____ d. University or school sponsored programs
3rd-3____ e. Structured Business/professional programs (Ex.NAHB, Architectural, Builder, Suppliers)
2nd-2 ____ f. Governmental programs (Ex. Corporation Commission, U.S. Department of Energy)
1st-1____ g. Building Codes
3rd-1 h. Other "experience" ____________

2b. Did you understand before the construction of the subject home, how the passive solar aspects of the design of the home could allow the sun to contribute significantly to the heating of the home during the winter?
Yes 4___
No 1___

2c. Do you understand it now?
Yes __
No ___

2d. If yes to 2b or 2c, which of the following significantly contributed to that understanding? (rank the first 3 in order using 1,2, and 3 in the blank.)

______ a. Consumer / popular magazines
2nd-1 b. Professional or trade magazines
1st-3 c. Utility company programs
2nd-1 d. University or school sponsored programs
3rd-2 e. Structured Business/ professional programs
2nd-1 f. Governmental programs
g. Building Code
3rd-1 h. Architectural Drawings
1st-1 i. Other Experience ______
(please list)

3a. Did you understand before you constructed the home how the passive solar aspects of the design could protect the home from significant summer heat gain and thus help reduce the air conditioning expense?

Yes 4_

No 1_

3b. Do you understand it now?

Yes______

No ______

3c. If yes to 3a or 3b, which of the following significantly contributed to that understanding? (rank the first 3 in order using 1,2, and 3 in the blank.)

____ a. Consumer / popular magazines
____ b. Professional or trade magazines
____ c. Utility company programs
____ d. University or school sponsored programs
____ e. Structured Business or professional programs
____ f. Governmental programs
____ g. Building Code
____ h. Architectural Drawings
____ i. Other "same as 2d" ______

4a. Does your company have a method of rating the energy efficiency of a home?

Yes 5

No __

4b. If yes to question 4a, what best describes the energy rating system used?

3 based on the Energy Audit system
2 based on total load predictions
based on load per square foot predictions
based on actual usage after home has been in use
Other, Please describe the rating system

4c. Please list the energy use for the subject home since the beginning of the service, if possible. provide at least the last 12 months of energy use. Provide figure for quantity use and total dollar cost.

(quantity) (cost)

4d. How would you rate the subject home for energy efficiency compared to other homes served by your company?

3 much less energy consumption than average
__ less energy consumption than average
2 average energy consumption
more energy consumption than average
much more energy consumption than average

4e. Please state a percentage of energy saving for the subject home?

____

5a. Has your company ever provided energy to an energy efficient home before the subject home?

Yes _5___
No ____

5b. If yes to question 5a, How many energy efficient homes has your company provided service to prior the subject home? ________ (insert the number in the blank)

6a. Have you been in the subject home after it was occupied and operating?

Yes 1 _
No 4

6b. If yes to the 6a, how would you best describe the thermal comfort of the subject home when compared to other homes?

significantly more comfortable
more comfortable
about the same
less comfortable
significantly less comfortable
1 not able to judge

7. Considering the costs and benefits of the energy efficient construction technology employed in the construction of the subject home, do you consider the technology any of the following:

a. too difficult to be employed in any homes other than custom built homes Yes____ No__4__
b. too expensive to be employed in any homes other than custom built homes Yes____ No __4__
c. enough of an advantage to use in the construction of other homes you are considering to build Yes _4__ No ___
d. The technology is too much of an economic risk to use in the construction of another home Yes____ No _4__

8. Do you view the construction of the passive solar / energy efficient home as an effective means to reduce utility company peak load demand.

Yes 4

No 1

9. Do you view the dealing with the owner's or builders of a passive solar / energy efficient homes to be any more or less complicated than those of the conventional home?

	More	Less	The Same
Builder	2		2
Owner	2		2

10. Do you consider the construction of an energy efficient / passive solar home to be a risk in any of the following categories?

	Visual	Financial	Social
Yes	1 "could be"	1 "somewhat"	
No	3	3	4

11. Do you consider the conservation of energy important?

In home construction		In automobile selection	
5	very important	1	very important
	moderately important	2	moderately important
	important	2	important
	moderately unimportant		moderately unimportant
	not important at all		not important at all

12. Do you think that the additional cost of energy efficient or passive solar technology in residential construction is low enough that it should not present a financial barrier to wide spread trial and usage?

Yes 3 "should not be but perception exists"

No 2

13a. Do you deal with builders and owners of new houses when they sign up for initial service?

Yes 4

No

13b. If yes to 13a, do you or your company offer to teach the owners or builders of new homes how to construct the new home to be more energy efficient?

Yes 3

No 2

14a. Do you, or does someone from your company, inspect new homes under construction to provide guidance on how to construct more energy efficient homes to the builders or owners?

Yes 4

No

14b. If you have answered yes to 13b or 14a, Have you found the builders to be receptive and willing to learn techniques of energy efficient construction.

Yes 4

No ____ Not able to judge 1

14c. If you have answered yes to 13b or 14a, Have you found the owners to be receptive and willing to learn techniques of energy efficient construction.

Yes 3

No ____ Not able to judge 2

15a. If energy efficient / passive solar construction technology is to be learned by the construction trades, through what organization or method should be used to achieve the technology transfer? (rank the first 3 in order in each category using 1,2, and 3 in the blank.)

Informal

3rd-1 a. Consumer / popular magazines

1st-3 3rd-1 b. Professional or trade magazines

3rd-1 c. Building Code

1st-1 2nd-2 3rd-1 d. Architectural Drawings

1st-1 2nd-2 e. Other "consumer demand

(please list)

Formal

1st-3 2nd-1 f. Utility company programs

1st-1 2nd-2 3rd-1 g. University or Vo-Tech school programs

1st-1 2nd-1 3rd-2 h. Structured Business or professional programs (Ex. NAHB)

2nd-1 3rd-1 ____ i. Governmental programs (Ex. Oklahoma Corporation Commission)

____ j. Other

(please list)

I hereby authorize the use of my name and / or the name of my company in, or in connection with, the written study.

LENDING INSTITUTION OFFICER QUESTIONNAIRE

Your name will not be used in the report unless you specifically grant permission ....

A. Owner of the Energy Efficient home under Consideration
____

B. Home Location ______________________________

C. Building contractor or Home Builder ______________________________

D. Lending institution ______________________________

Officer's name and title ______________________________

****

1a. Are you in a position to approve or disapprove construction and new home mortgage loans?

4 Yes (with committee approval)

No

1b. Before making a loan do you, or does someone with the institution, review building plans of the proposed home to be constructed?

4 Yes (3 are done by outside consultants)

No

If yes, what is the primary purpose of the plan review? Please rank 1,2,3-(1 is most important)

1st-4 To establish value

2nd-4 To establish size (cost per sq.ft.)

3rd-4 To establish energy efficiency (2 R-value only

1c. Before making a loan do you or someone with the institution figure the probable cash flow of the loan applicant?

4 Yes

No

1d. If yes to question 1c, does the institution consider probable energy or utility cost of the residence in the cash flow calculations?

2 Yes (energy eff. home lowers living expense allowance)

2 No

1e. If yes to question 1d, which of the following methods best describes how this is done:

a. A flat utility cost is figured for all homes.

b. A per square foot multiplier is used for all homes.

c. The local utility company is asked to approximate the monthly utility cost for each home.

1 d. The owner or builder are asked to approximate the monthly utility cost for each home.

1 e. Other ______________________________

1f. Energy costs were a factor on the approval of the the loan for the subject home.
_1_Yes
_3_No

2. Are loans ever turned down or not made on a home for any of the following reasons? Check as many as are applicable.
_0_The home will cost too much to maintain
_0_The projected utility costs are too high
_4_The home "look" or appearance is not of broad enough appeal to resell if the loan goes into default.
_2_The home presents some financial risk because of the technology used in construction.
_4_The home presents some "social" risk.(location important)
_4_The home does not have a furnace.(dependable heat source)
Other reason having to do with the appearance or technology used in the construction of the home.

3a. Do you feel there is more, or less financial risk involved in making a loan on an energy efficient home?
More _1_ Same
_2_ Less _1_ Not able to judge

3b. Do you or does the institution usually know the energy efficiency of the homes on which it makes loans?
_2_Yes
_2_No

4. Does the lending institution have trouble (late payments or foreclosure) with any home loans because of rising energy costs?
_2_Yes _1-4%_ number or percentage
_2_No 1-"no figures, but a factor"

5. There seems to be some confusion as to the definition of "energy efficient" as it is used to describe how well a house is constructed. Which of the following definitions more closely coincides with your personal definition of "energy efficient"? Please check the appropriate blank. If your definition varies somewhat from the given definition, please write in your definition in the "variation" blank given.

_1_a. DOLLAR AMOUNTS OF UTILITY BILLS FOR OPERATIONAL COST
A home would be "energy efficient" if the total dollar amount of utility bills was below $ 100/mo.
An alternative would be the dollar amount of the utility bills as compared to the size of the home, i.e. $ ___ per square foot of living area
** If you checked the "a" blank please fill in a dollar amount in the blanks given.

_3_b. AMOUNTS OF INSULATION AND CONSTRUCTION MATERIAL QUALITY
A home would be "energy efficient" if the home has the which of the following materials: check the items are appropriate for your definition.
_3__ R-38 ceiling insulation,
_3__ 2 x 6 exterior wall studs with R-19 insulation
_1__ R-15 perimeter insulation below the floor around the outside perimeter of the living space (stem wall insulation or floor insulation).
_3__ Has double (thermo-pane) or storm windows
____ Has thermo-break aluminum or wood window frames
_2_ Other "Heat pump if no natural gas" ____________

Variation on b. ______________________________

___c. QUANTITY OF AUXILIARY HEAT REQUIRED (NATURAL GAS, ELECTRICITY, OR ETC.) USED, AS COMPARED TO THE COOLING OR HEATING LOAD CAUSED BY THE WEATHER
A home would be "energy efficient" if it used less than _____(quantity) British Thermal Units of electricity or natural gas for every heating and cooling degree day, i.e. BTU per square foot per heating or cooling degree day.
Variation on c. ______________________________

___d. EFFICIENCY OF HEATING OR COOLING DEVICES USED IN THE HOME
A home would be "energy efficient" if the home used which of the following methods or devices to heat and / or cool the house:
___Electric resistance heat (the home gets to use 100% of the kilowatts purchased in heat)
___Electric heat pump with a Coefficient of performance above _____(state the amount, ex. 2.5)
___ A wood burning stove
___ A ground loop (water to air) heat pump
___ A heat pump for heating domestic hot water
___ Active solar panels and system to heat the space or domestic hot water
___ Other ______________________________
Variation on d. ______________________________

6. What is your major source of information on energy efficient residential construction? (rank the first 3 in order using 1,2, and 3 in the blank. Number 1 is the most important.)
1st-1 3rd-1 a. Consumer / popular magazines
1st-1 2nd-1 b. Professional or trade magazines
2nd-1 3rd-1 c. utility company programs
2nd-1_____ d.University or school sponsored programs

2nd-1 1st-1 e. Structured Business or professional programs (Architectural, Builder, Suppliers)
3rd-1 f. Governmental programs (Example: Corporation Commission)
2nd-1 g. Building Codes
0 h. Other ______

7. Do you understand how the passive solar aspects of the design of a home could allow the sun to contribute significantly to the heating of your home in winter?
2 Yes 1 Read about it
1 No

8a. If yes to 6, which of the following significantly contributed to that understanding?
1st-1 3rd-1 a. Consumer / popular magazines
2nd-2 b. Professional or trade magazines
3rd-1 c. utility company programs
2nd-1 d. University or school sponsored programs
3rd-1 1st-1 e. Business or professional programs (Architectural, Builder, Suppliers)
0 f. Governmental programs (Example: Corporation Commission)
0 g. Visiting the subject home
1 h. Other "friend who sells solar equip" ______

9b. Do you understand how the passive solar aspects of the design of a home could protect a home from significant summer heat gain and thus help to reduce your air conditioning expenses?
2 Yes 1 Read about it
1 No

9c. Which of the following significantly contributed to that understanding? (rank the first 3 in order using 1,2, and 3 in the blank. Number 1 is the most important.)
1st-1 3rd-1 a. Consumer / popular magazines
2nd-2 b. Professional or trade magazines
3rd-1 c. utility company programs
2nd-1 d. University or school sponsored programs
3rd-1 1st-1 e. Business or professional programs (Architectural, Builder, Suppliers
0 f. Governmental programs (Ex: Corporation Comm.)
0 g. Visiting the subject home
1 h. Other "friend"

10. Considering the costs and benefits of the energy efficient technology employed in the construction of the subject home, do you consider the technology any of the following:

a. too difficult to be employed in any homes other than custom built homes
   ___ Yes
   _3_ No
   _1_ Not in a position to judge
b. too expensive to be employed in any homes except custom built homes
   _1_ Yes
   _3_ No
c. enough of an advantage to construct other homes you might be building to use the same technology.
   _3_ Yes ___ No
   _1_ Not in a position to judge
d. The use of the technology is too much of an economic risk to use in the construction of other homes.
   _1_ Yes "slightly larger initial investment"
   _3_ No

11. Are you and are others satisfied with the exterior appearance of the subject home? Check the one that most closely describes your satisfaction level, and the satisfaction level of others you might have spoken with concerning the home.

You		Others	
3	very satisfied	2	very satisfied
	moderately satisfied	___	moderately satisfied
	satisfied	___	satisfied
	moderately dissatisfied	___	moderately dissatisfied
	dissatisfied	___	dissatisfied
1	no comment-have not seen	2	no comments

12. Do you view the construction of the subject passive solar / energy efficient home a visual success?
_3_ Yes
___ No
_1_ Unable to judge

13. The subject home is heated using __________. The subject home is cooled using and electric__________ system. The energy costs for the subject home are $______/month or $______per month per sq. ft. How does either figure compare with other homes with which you are familiar?
___very much higher
___higher
___about the same
_2_lower
_2_very much lower

14. Do you view building a passive solar / energy efficient home to be any more/less complicated than the building of a conventional home?

	More	Less	The Same
In Construction	1		3
In Financing	1		3
In Dealing with the Utility Co.			3

15. Do you see any social risk in building a home such as the subject home, i.e. using passive solar or energy efficient construction technology?
__ Yes 2 No
2 Slight (location specific)

16. Do you consider the conservation of energy important? Check the blank next to the words that best describe your level of importance.

In Home Construction		In Automobile Selection	
3	very important	2	very important
	moderately important		moderately important
1	important	2	important
	moderately unimportant		moderately unimportant
	not important at all		not important at all

17. Do you consider passive solar or energy efficient residential construction to be cost effective?
4 Yes
__ No

18. Do you think that the additional cost of energy efficient / passive solar technology in residential construction is low enough that it should not present a financial barrier to wide spread trial and usage?
3 Yes
__ No 1 Not able to judge

19a. Have you ever been in the subject home after it was occupied and operating?
2 Yes
2 No

19b. If yes to 19a, Are you able to judge the thermal comfort of the home?
__ Yes
4 No

19c. If yes to 19b, how would you best describe the thermal comfort of the subject home when compared to other homes with which you are acquainted?
__ significantly more comfortable
__ more comfortable
__ about the same
__ less comfortable
__ significantly less comfortable

20. Do you or someone with the institution encourage the loan applicants to construct energy efficient homes?
3 Yes
1 No

21. Do you view the energy efficiency or passive solar technology used in the subject home as a financial risk?
1 Yes
3 No

22. Do you think it is possible to have an energy efficient, inexpensive home?
3 Yes
No 1 Not able to Judge

23. Do you think there should be more energy efficient homes available "for sale" on the market?
4 Yes
No

24. If there are to be more energy efficient homes constructed, on which decision makers should education efforts be focused? (Rank 1,2,3,4) 1 is the most important
1st-2 2nd-2 Builders
1st-2 2nd-2 Home Owners
3rd-4 Mortgage Bankers/ loan officers
4th-4 Utility Company

25. If energy efficient / passive solar construction technology is to be learned by the persons involved with the energy efficient construction technology, through which organization or method should be used to achieve the technology transfer? (Rank the first 3 in order in each category using 1,2,3, in the blank.)

Informal

2nd-2 a. Consumer / popular magazines
1st-1 2nd-1 3rd-1 b. Professional or trade magazines
1st-2 c. Building Codes
1st-1 3rd-3 d. Architectural Drawings
2nd-1 e. Other Lending Instutions

Formal

3rd-3 f. Utility company programs
1st-1 2nd-1 g. University or Vo-Tech sponsored programs
1st-3 2nd-1 h. Structured Business or professional programs (Example: NAHB)
1st-1 i. Governmental Programs (Example: Oklahoma Corporation Commission)
j. Other

I hereby authorize the use of my name and / or the name of my company in the written study.

VITA

Kenneth Paul Larson

Candidate for the Degree of

Master of Science

Thesis: AN ANALYSIS OF ENERGY EFFICIENT/PASSIVE SOLAR HOUSING WITH IMPLICATIONS FOR TECHNOLOGY TRANSFER IN OKLAHOMA

Major Field: Environmental Science

Biographical:

Personal Data: Born in Spring Valley, Minnesota, March 25, 1937, the son of Guy L. and Esther G. Larson. Married to Shirley K. Sullins on January 26, 1981.

Education: Graduates from Ames High School, Ames, Iowa, in June, 1955; received Bachelor of Architecture degree from the University of Illinois, Urbana, Illinois, in May, 1960; completed requirements for the Master of Science degree at Oklahoma State University in July, 1986.

Professional Experience: Captain, United States Marine Corps, June, 1960 to August, 1963; Research Staff, Iowa State Planning Commission, August, 1963 to March, 1964; Architectural Designer, Amos Emery and Associates, Architects, Des Moines, Iowa, March, 1964 to August, 1965; Architectural Designer, Stade, Dolan, and Emerick, Architects, Park Ridge, Illinois, August, 1965 to January, 1968; Project Designer, The Perkins and Will Partnership, Chicago, Illinois, January, 1968 to January, 1969; Associate Architect, Emery-Prall and Associates, Architects, Des Moines, Iowa, January, 1969 to January, 1971; Partner, Larson-Prall Architects and Planning Consultants, Des Moines, Iowa, January, 1971 to August, 1972; Executive Vice-President/Architect, John D. Bloodgood Architects, P.C., Des Moines, Iowa, August, 1972 to August, 1980; Visiting Assistant Professor of Interior Design, Department of Housing, Interior Design, and Consumer Studies, Oklahoma State University, August, 1980 to June, 1985; Visiting Associate Professor of Interior Architecture, College of Architecture, University of Oklahoma, August, 1985 to present.