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FACTORS AFFECTING HOME-BUILDERS' DECISIONS TO USE ENERGY-EFFICIENT FEATURES IN NEW CONSTRUCTION: A QUALITATIVE STUDY OF THE GREATER LANSING AREA

presented by

Gregory Hugh Evenstad

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By

Gregory Hugh Evenstad

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ABSTRACT

FACTORS AFFECTING HOME-BUILDERS' DECISIONS TO USE ENERGY-EFFICIENT FEATURES IN NEW CONSTRUCTION: A QUALITATIVE STUDY OF THE GREATER LANSING AREA

By

Gregory Hugh Evenstad

The purpose of the study was to conduct a qualitative study of the factors which influence the home-builders' decisions to include or not include energy-efficient features in new housing construction.

A sample of 15 builders was utilized (divided into two groups), those which were very energy conscious (group A) versus those which were not as energy conscious (group B). The information utilized in this study draws a comparison of: home-building firm characteristics, knowledge of heat loss/gain calculations, use of subcontractors, decision criteria, energy features used, (if any), risk factors, steps to insure a tighter house, and energy costs versus monthly savings.

Results of the analysis showed that group A tended to be more involved in decisions specifying type and capacity of heating/cooling systems, be more concerned about energy, work more closely with subcontractors, build smaller, less costly, more energy-efficient homes which utilized more energy features. These builders also stated problems in getting features properly installed as their most important risk. Cost, marketing and reducing infiltration were found

as key factors in decision making for both groups. No comparative differences were noticed in age, education and experience of the home builders.

5/16/83

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A special thank you to Dr. Bonnie Morrison. Without her special interest, guidance, understanding and timely support this objective would not have been achieved.

To the United States Army and Corps of Engineer Branch, thank you for your support, and giving me the chance to receive an advanced degree.

To my wife Joan, Kurstin and Shannon for all the love and support that only a great family can give.

To Tim Mrozowski, my major professor, and Doug Cron, both from the School of Building Construction, for their support and guidance.

Finally, to Mom and Dad Evenstad for the support that only parents can give.

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Definitions

The following is a list of definitions that underpin the content of this study.

Barrel:	a liquid volume measure equal to 42 gallons (about 5.6 cubic feet).
Billion:	one thousand million or 10^9.
BtU:	"British thermal unit," the amount of heat energy that must be supplied to one pound of water to raise its temperature one Fahrenheit degree.
Building Envelope:	the elements or assemblies of a building which enclose conditioned spaces through which thermal energy may be transferred to or from the exterior.
Degree Day:	a unit based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter.
Energy Truss:	a truss design that has a raised heel which allows full insulation, even to the edges.
Fenestration:	the windows and doors of a building and how they are arranged.
Fossil Fuel:	any naturally occurring fuel of an organic nature -- usually used to describe coal, crude oil and natural gas.
HVAC:	a system that provides either collectively or individually the process of comfort heating, ventilating and/or air conditioning.

Infiltration: the uncontrolled inward air leakage through cracks and openings of any building element and around windows and doors of a building caused by the pressure effects of wind or differences in the indoor and outside air density.

Quadrillion: one thousand trillion or 10^{15}.

Resources: the estimated total quantity of a mineral in the ground, includes prospective undiscovered reserves.

Thermal Efficiency: the ratio of the energy delivered by a process to the energy extracted from the primary fuel feeding the process; both input and output are usually expressed in BtUs, and the ratio as a percentage (usually less than 100 percent).

Thermal Resistance (R): R value is a measure of the ability of a material to resist the flow of heat. The higher the R the better the insulation.

Thermal Transmittance (U): a measure of the ability of a single heat flow region to transmit heat. The combination effect of all materials including air space and surface film within the region or $U = 1/R$.

<u>Energy Equivalents</u>

Coal: 5,897 to 4,536 BtU combustion energy per kilogram or 13,000 to 10,000 BtU combustion energy per pound.

Crude Oil: 5.8 million BtU per barrel (138,000 BtU per gallon) combustion energy or 36,460 BtUs per liter.

Electricity: one kilowatt hour equals 3,412 BtUs.

Gasoline:	approximately 33,025 BtU combustion energy per liter or 125,000 BtU combustion energy per gallon.
Natural Gas:	1032 BtU combustion energy per cubic foot.

One quadrillion (10^{15}) BtU per year is equivalent to burning 472,000 barrels of oil or 2,660 million cubic feet of natural gas or 130,000 tons of coal per day.

1. INTRODUCTION

Having a comfortable home which uses less energy, saves money and at the same time provides a better place to live is a concept that everyone can support. The benefits of spreading our investment dollar, building more for less money, increasing efficiency, and cutting down our dependency on energy-intensive buildings (high-energy cost) needs to be recognized more today and pursued in the future. (Zimmerman and Hart, 1982).

Of all the energy expended in the United States approximately 23.5 percent (Johnson, 1976) is consumed for various purposes in the residence. Approximately 87.5 percent of the residential energy expenditure is used for the purposes of comfort-space conditioning (73.5%) and domestic water heating (14%) (Johnson, 1977). These percentages represent consumption conditions of most of the United States' present housing stock which was estimated to be 78 million units in 1975 (Johnson, 1977).

Most existing dwellings were designed and built at a time when energy was readily available and was comparatively low in price. Consequently, the energy performance of residental buildings was not given a high priority. Of the 23.5 percent energy consumed by a resident, 30 to 50 percent of that energy is wasted (Wright, 1973). The energy consumed by buildings can be reduced by 30 percent if buildings are redesigned (Zimmerman and Hart, 1982). With the cost of energy rising and availability decreasing, the need to provide energy-efficient designs becomes more important and a high priority. Existing homes or new homes built using past design and construction practices are considered wasteful of energy resources and are expensive to maintain at comfort levels. The purpose of this study then is to determine what factors have caused home builders to include or not include energy-efficient features in new residential home construction. Escalating energy costs are changing our design habits. It is no longer practical to design and build structures without specific reference to the projected energy consumption.

Our knowledge of reducing energy consumption must be expanded. This is especially true in relationship to the design life of projects, consumption rates, equipment efficiencies and system designs which contribute to waste of energy (Dumas, 1976; Zimmerman, 1982).

The primary objective of this study was to perform a qualitative comparative study of the factors that have caused home builders to include or not include energy efficient features in new construction within the Greater Lansing area. The primary objective incorporates the following secondary objectives:

1) Determine if any builder characteristics might have an effect on the use of energy efficient features in new construction.

2) Determine what might stimulate builders to consider putting energy-efficient features into a new residence.

3) Determine builders' estimates of the most important reason for consumer resistance to energy efficient features.

4) Determine the criteria the builder might use in making a final decision to use an energy-efficient feature.

5) Determine the risk factors involved in using energy-efficient features in new construction.

6) Determine what the builders' suggested steps are to insure a tighter more energy-efficient home.

7) Determine what obstacles the builder has in building an energy-efficient home.

8) Determine if builders will cut insulation to save costs and determine dollar amount added to the monthly mortgage payment versus dollar amount in savings to the buyer.

2. REVIEW OF LITERATURE

2.1 Energy Resources and Consumption

In the past energy resources have been assumed to be an inexhaustible commodity. Investigation and research of the design of building structures showed that designs in the past focused primarily on the initial cost of getting the building into operation (Wright, 1973). No real consideration was given to energy conservation and it was assumed that the cost of fuel to heat, cool, ventilate, light and power the operating equipment would be paid by the owners.

The interest in energy-efficient designs in residential housing is growing. Part of this reason is the dwindling supply of fuels and increased dependence on other nations for energy to maintain our economy in the United States (Yergin and Hillenbrand, 1982).

The sources of the energy problems require further analysis to understand how we suddenly arrive at an energy deficit.

According to Gibbons and Chandler (1981) the history of energy has gone through two major transitions, wood to coal in 1880 and coal to oil in the 1940s.

Oil was first discovered in 1859 by Colonel Edwin Drake in Pennsylvania and sold for 20 dollars a barrel and quickly fell to 10 cents per barrel when oil was discovered in Texas in 1901. As the automobile came into being at the turn of the century, oil quickly came into demand.

The magnitude of the demand changed drastically when the transition of coal to oil took place and drive-in filling stations became available. The demand for petroleum rose from slightly more than two quadrillion BtU (quads) per year in 1859 to more than 20 quads in 1941, to now almost 80 quads per year (Gibbons and Chandler, 1981).

Prior to the Arab Oil Embargo of 1973 there was little comprehensive energy analysis available.

Fuels were used in meager quantities for cooking, heating of homes and public building facilities, and for the manufacture of metals and glass. Bowersox (1978) stated that industry at the start of the Industrial Revolution centered around waterways to benefit from nature's free source of power. The invention of the steam engine brought about a new source of power and helped start the Industrial Revolution. Dumas (1976) stated that the standard of living rose as new technology and conveniences were introduced. Industry expanded and man's production multiplied.

Our dependence on energy and our corresponding consumption of energy, as O'Callaghan (1981) stated, were in full swing by 1950. The 1981 Annual Report to Congress (Figure 2.1 and Appendix A) shows the consumption of energy by type and it also shows how the consumption of energy especially petroleum has increased.

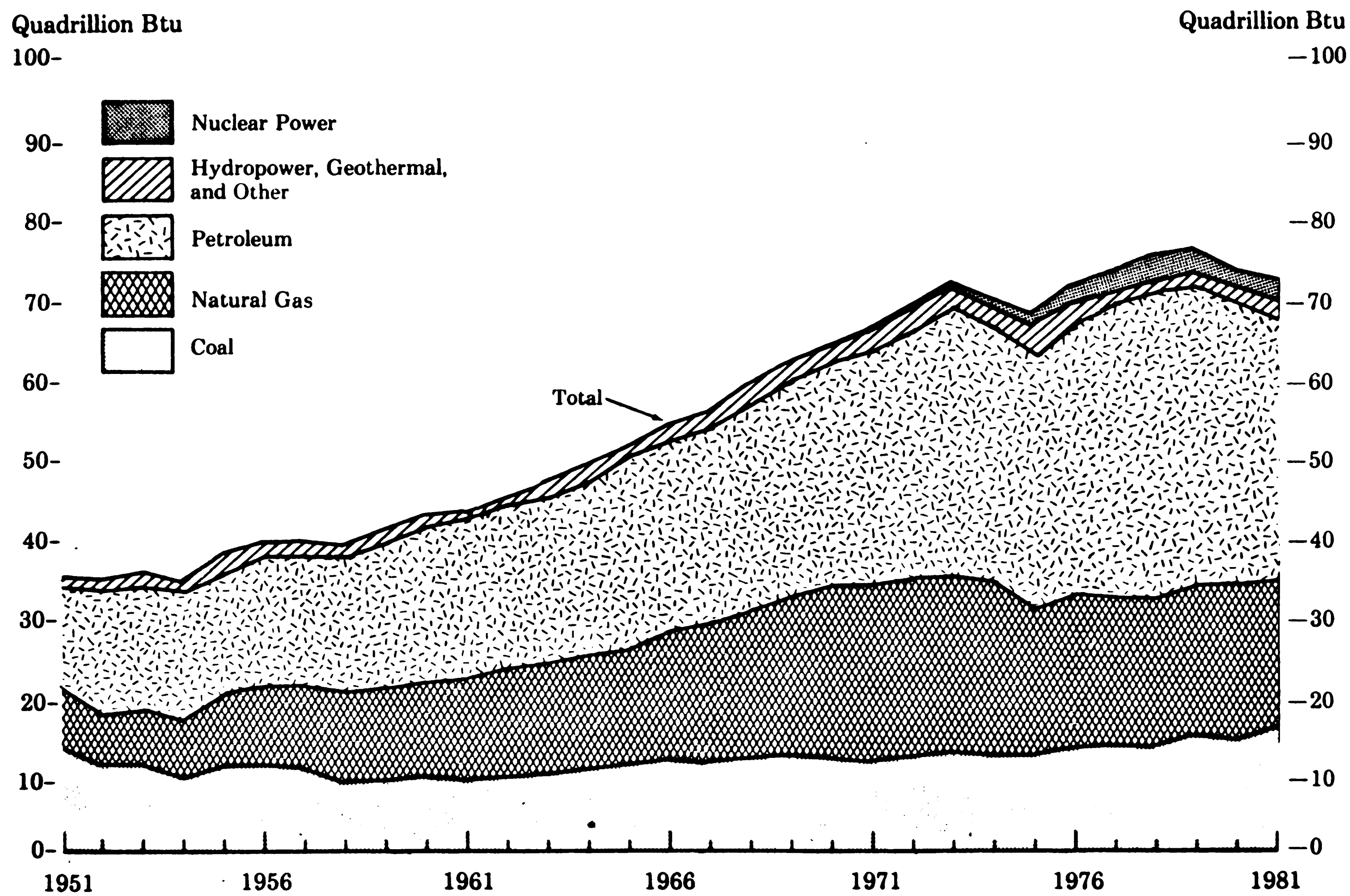


Figure 2.1 Consumption of Energy by Type

Source: 1981 Annual Report to Congress, Energy Statistics Volume 2 of 3, (DOE/EIA-0173(81)12) May 1982, p. 6

According to White (1971), our total energy demand has risen steadily with the increase in population and with the improvements in our lifestyles. National Petroleum Council report (1972), White (1971), Wilson (1979), Zimmerman and Hart (1982) all showed a historical and projected growth rate of 3.5 percent from 1955 to 1970. The growth rates through the '70s were approximately 4 percent as shown in Figure 2.2.

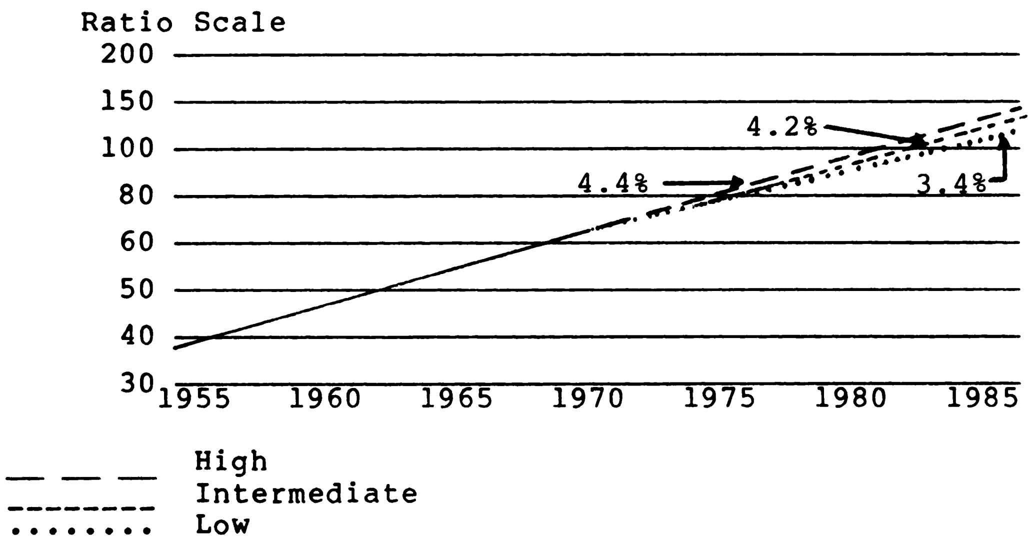


Figure 2.2 Historical and Projected U.S. Energy Demand (Quad. Btu)

Source: <u>Guide to National Petroleum Council Report on United States Energy Outlook</u>, National Petroleum Council, Washington, D.C., December, 1972, p. 15

Further research and analysis of U.S. energy consumption trends, White (1971), Wilson (1979), and the 1981 Annual Report to Congress as shown in Figure 2.3, shows the uniform increase by end-use sector from 1951 to 1979. Burby and Marsden (1980) stated that during the 1950s and 1960s increased consumer purchasing power and the accompanying greater use of inefficient electrical heating, air conditioning and other appliances pushed the rate of growth of residential energy consumption to 3.5 percent per year. A slight decrease in consumption is shown for 1980 and 1981, which is a result of more efficient equipment and structures, and changes in energy consumption behavior and attitudes. A slight decrease in consumption is also noticed between 1973 to 1975 which resulted from the impact of the Arab Oil Embargo on the United States. Data supporting Figure 2.3 is located in Appendix B.

2.2 Energy Cost Escalation

Adding to the problem of energy consumption is the problem of rising costs as shown in Figure 2.4 and Appendix C. From 1973 to 1981 the price of crude oil increased fourfold (Yergin and Hillenbrand, 1982), which is also evidenced in Figure 2.4. With the rate of growth in residential energy consumption, considerable attention has been devoted to saving energy in the residence by reducing home utility costs, Socolow (1978) and Burby and Marsden (1980). As energy prices have risen, the consumption rate has slowed

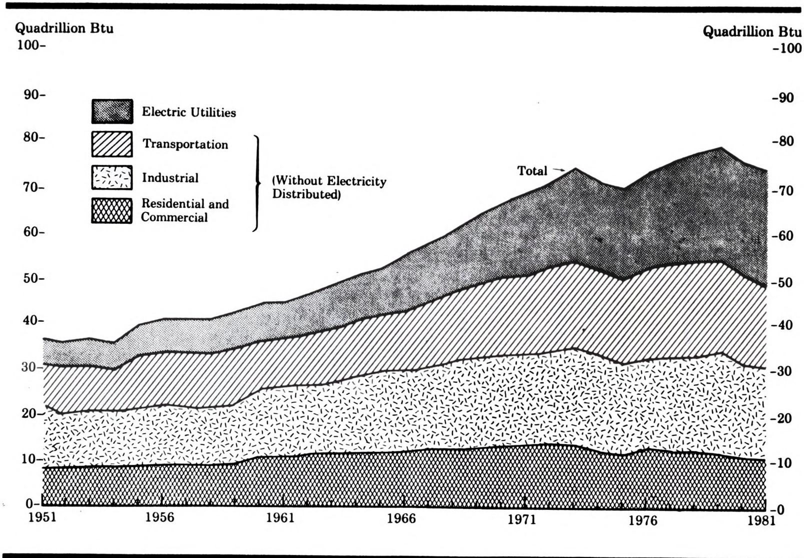


Figure 2.3 Consumption of Energy by End-Use Sector

Source: 1981 Annual Report to Congress, Energy Statistics, Volume 2 of 3, (DOE/EIA-0173(81)12) May 1982, p.8

which was evidenced in Figure 2.1. Socolow's experiment at Twin Rivers, New Jersey (1972-1977) found that almost one-half the energy cost variance in similar houses relates to different behaviors. The attitude and behavior within the household through the construction and day-to-day operation can have a major effect on reducing energy costs within the residence (Burby and Marsden, 1980).

Energy costs continue to increase as a result of supply and demand which is shown by the United States trade for energy in Figure 2.5 and Appendix D, and also because of the result of worldwide control of oil and energy resources (Energy Fact Book, 1980, 1981 Annual Report to Congress). Dependence on oil as the primary energy source has added to the energy situation. The consumption trend toward the use of petroleum products shows our dependence on oil as a source of energy. This same concept is shown in construction, where construction depends on oil.

The building and construction field in 1940 changed its consumption of coal to oil due to oil's cleanliness in burning and energy conversion efficiency as shown in Table 2.2 provided by Dumas (1976).

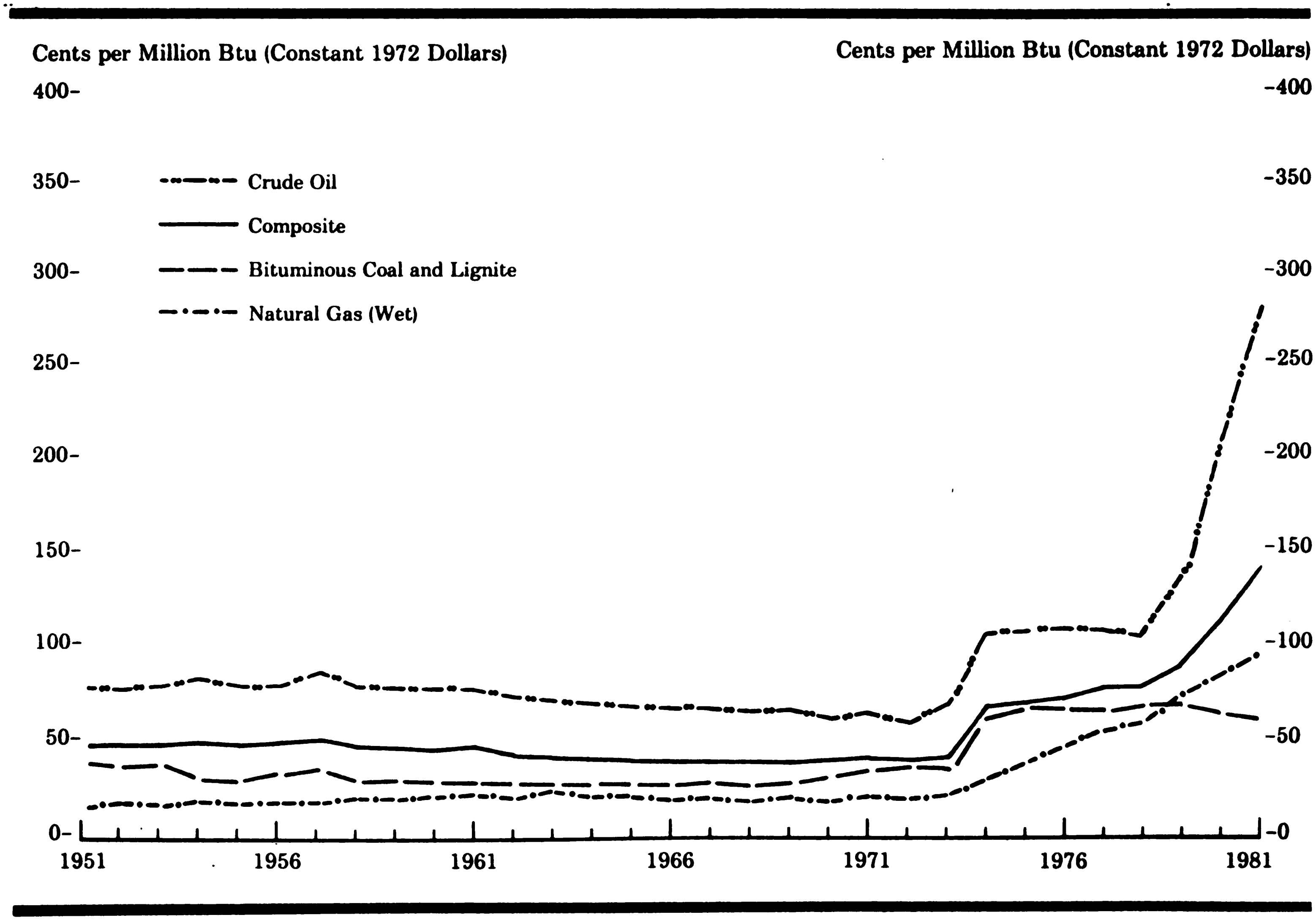


Figure 2.4 Prices of Domestically Produced Fossils Fuels

Source: 1981 Annual Report to Congress, Energy Statistics, Volume2 of 3, (DOE/EIA-0173(81)12) May 1982, p.20

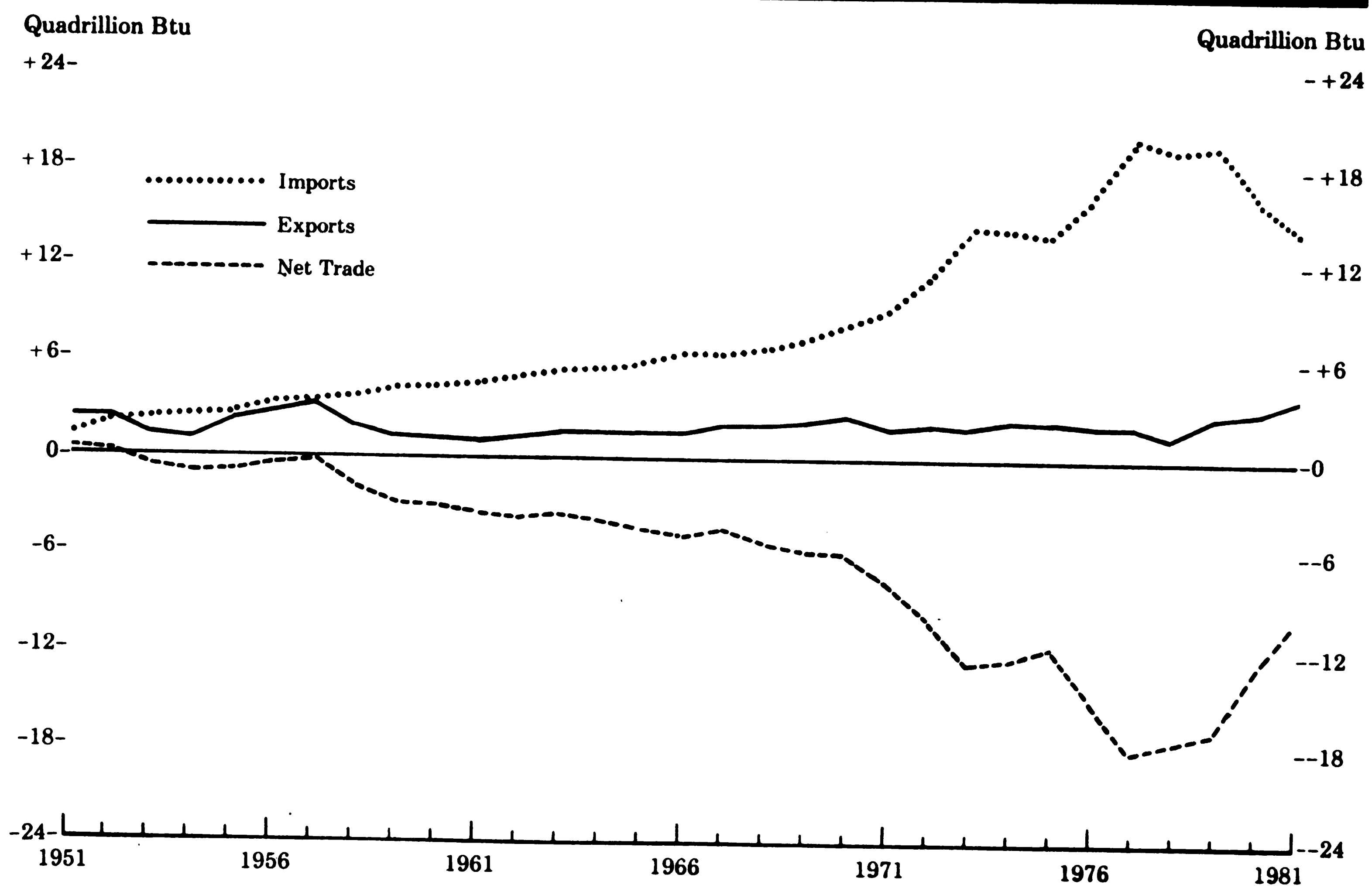


Figure 2.5 Trade in Energy

Source: 1981 Annual Report to Congress, Energy Statistics, Volume 2 of 3, (DOE/EIA-0173(81)12) May 1982, p.14

Table 2.2 Comparison of Energy Efficiencies of Fossil Fuel and Electric Resistance Heating Systems

	Space Heating	
	Rated	Actual Residential
Natural Gas	85%	75%
Petroleum Products	80	63
Coal	70	55
Electric	38	31
(at heater)	(95)	(95)

	Water Heating	
	Rated	Actual Residential
Natural Gas	70%	64%
Petroleum Products	55	50
Coal	70	15
Electric	37	30
(at heater)	(92)	(92)

Source: Modified from, Dumas, Lloyd, J., 1976, "Building Design and Engergy Consumption," *The Conservation Response*, Lexington: D.C. Heath and Company, p. 57.

Dumas (1976) also pointed out that the efficiency of an electric resistance heater is about 95 percent, but when using the efficiency of 40 percent for the electric generating plant, the overall efficiency of electric heating would be only 38 percent, far below the efficiencies of fossil fuel heaters.

Stobaugh and Yergin (1979) reported that during the 1950s and 1960s, efficient energy usage was increasingly neglected in the construction of new buildings and homes.

Stobaugh and Yergin (1979) also stated that in New York City, office buildings constructed between 1945 and 1950 used half as much energy per square foot as those built between 1960 and 1965. The differences they stated were due to several factors: older buildings used natural light and had windows left open, whereas the newer buildings are sealed and depend on mechanical systems for lighting, heat and air conditioning. Gibbons and Chandler (1982) did a similar study of an office building in Manchester, New Hampshire, and found a 20 percent savings could be achieved between a conventional design and an energy-conserving design by including no north-facing windows, reducing over-all window area, increasing insulation and thermal mass and providing an efficient heating and ventilation system along with other design features listed in Figure 2.6. This same concept was evidenced throughout the housing industry until the 1970s, when energy-conservation policies were established.

A study by Johnson in Wright (1973), showed the accumulated fuel cost savings from improved insulation (for various annual percentage increases in fuel prices) could reach 250 billion dollars over a 20-year period. Based on the projected increase of the nation's housing stock to 100 million units over the next 20 years, Johnson, in Wright (1973), made two assumptions. (1) Insulation levels would be improved 10 percent for existing housing through

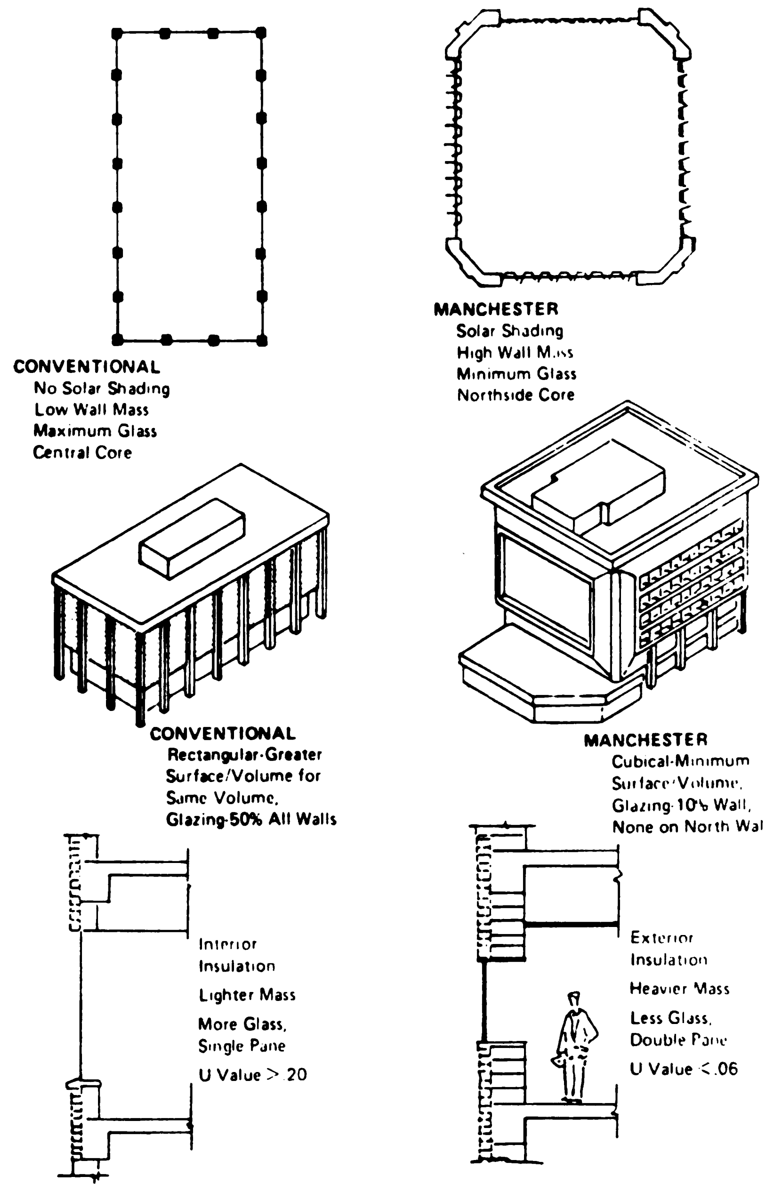


Figure 2.6 Energy conservation vs. Conventional Design

Source: Gibbons, J.H., and Chandler, W.U., <u>Energy: The Conservation Revolution</u>, (Plenum Publishing Corporation, New York, New York, 1981), p. 174

retrofitting and 50 percent for new houses. (2) The energy prices would run at the 1970 level or up to a 10 percent annual increase.

2.3 Energy Conservation

In 1970, some 111 years after the birth of the American oil industry, domestic production peaked and began to decline (Stobaugh and Yergin, 1979). But the demand for oil continued to escalate, and that demand could be met only by more and more oil from the Middle East, which meant increasing dependence on foreign sources. Zimmerman and Hart (1982) stated that in the 1960s a trend toward oil as a source of energy and the increase in consumption resulted in the import of 15 percent of the crude oil used in the U.S. In 1976, the U.S. relied on imports for over 40 percent of petroleum energy needs and for today the U.S. imports 50 percent of its energy needs (Zimmerman and Hart, 1982).

The first oil shock, in late 1973, caused by the Arab Oil Embargo marked the end of secure and cheap oil.

OPEC countries stopped negotiating a price for oil and unilaterally set the price on a take-it-or-leave-it basis. Oil buyers had only one choice, paying the higher price, eight times higher by the end of 1974 than five years earlier (Stobaugh and Yergin, 1979). Yergin and Hillenbrand (1982) stated the declared aim of American policy has been to reduce the use of imported oil, yet the United States has in fact become more and more dependent on imported oil.

According to Stobaugh and Yergin (1979) there are conventional sources for domestic energy: oil, natural gas, coal and nuclear power, and there are unconventional sources: policy decisions and conservation. Among all the sources, conservation presents itself as the most immediate opportunity to reduce dependence on imported oil. Conservation is regarded as an untapped source of energy. But the decisions to conserve, have to be made by millions and millions of often poorly-informed people.

What does conservation mean? In Gibbons and Chandler (1982), conservation was defined as "wise use" and placed in three categories: (1) obtaining higher efficiency in energy production and utilization, (2) accommodating behavior to maximize personal welfare in response to changing prices of competing goods and services, and (3) shifting from less to more plentiful energy resources. Yergin and Stobaugh (1979) also identified three categories of energy conservation. The first category is curtailment. When supplies are interrupted, energy conservation is forced as factories are closed and work is lost. The second category is overhaul, changing the way Americans live and work, which is a long slow process. The third category is adjustment, making houses, automobiles, industrial processes and home appliances more efficient and capturing waste.

Of the three categories, Yergin and Stobaugh (1979) favored adjustment for energy conservation, which encourages changes in equipment, capital stock and daily behavior that promote energy savings in a manner that has economic and social justification.

Schipper and Dormstadter, in Stobaugh and Yergin (1979), warned "The most impelling factor in encouraging conservation action is the cost of not conserving."

2.4 Emergence of Building Energy Performance Policy

With 23.5 percent (Johnson, 1976) of the total energy consumption in the United States coming from the residential environment, individuals started looking for ways to get away from increasing utility bills through improving the energy performance of their houses. To improve the energy performance of existing homes and in new construction, the development of energy performance criteria came about to serve as guides. Publications became available concerning energy conserving actions applicable to existing buildings and new construction (Federal Energy Administration, 1977; Burby and Marsden, 1980; Peterson, 1974; Ovimance criteria came about to serve as guides. Publications became available concerning energy conserving actions applicable to existing buildings and new construction (Federal Energy Administration, 1977; Burby and Marsden, 1980; Peterson, 1974; Oviatt, 1975).

The federal efforts to meet the energy conservation challenge, as stated in the Energy Policy and Conservation Act of 1975, the Energy Conservation and Production Act of

1976, and the bills comprising the National Energy Act of 1978 (from Burby and Marsden, 1980) had four major thrusts.

1. Mandatory federal appliance efficiency standards were to be established by 1980 for 13 categories of home appliances, ranging from furnaces to television sets.

2. To promote the installation of additional insulation (the national goal was to insulate 90 percent of all homes by 1985) and other structural retrofits; public utilities were required to provide home-energy audits and conservation advice to households. Weatherization loans and grants for low- and moderate-income families and the elderly have been provided. Income-tax credits for home insulation have also been available.

3. To promote energy efficiency in new residential construction, mandatory standards for new buildings are being developed by the Department of Housing and Urban Development for implementation through state building codes.

4. To promote more rapid adoption of solar-energy technology and the implementation of income-tax credits for homeowners who use solar.

A combination of the above measures were expected to result in reduced oil import needs by 1985, increased use of fuels other than oil and gas, as well as, promote more efficient and equitable uses of energy in the United States.

Formal energy performance standards have been developed pertaining to new building construction. ASHRAE Standard 90-75 (ASHRAE, 1975) began development in 1973 with the joint emergency workshop on energy conservation in buildings (Berry, 1975) and gained final approval in 1975. In 1977, ASHRAE Standard 90-75 was adopted along with several other rules and became the Michigan Energy Code (1976).

New building energy performance criteria and policies will continue to be developed and existing ones revised. ASHRAE Standard 90-75 has been revised (ASHRAE/IES, 1980), the Michigan Energy code (1981), and a program was created to develop Building Energy Performance Standards (BEPS) (U.S. Dept. Energy, 1979).

The reason for the changes was due to more emphasis being placed on energy-efficient designs and a greater emphasis on analyzing initial energy use and cost in the construction of a facility, than ever before.

Architects are now in a period of major reassessment in which the entire selection of materials and assemblies are being examined to see if they perform to satisfy energy conservation demands (Stein in Stobaugh and Yergin, 1979). Many of the assemblies that would normally be slowly phased out are being rejected, i.e., low efficient heating, ventilating and air-conditioning equipment (HVAC).

2.5 Factors Affecting Energy Consumption

The primary sources of energy usage start with the purpose and how energy is going to be used. Personal comfort levels and conveniences often influence the consumption rate of energy for a house more than the physical design and the structure, from experiments at Twin Rivers, New Jersey (Socolow, 1978). Energy conservation research has shown that major savings in energy may be realized through more efficient use, proper sizing of equipment, and operation within the house.

The proper sizing of comfort equipment is only one aspect of the overall strategy for the design and construction of houses which improve energy performance.

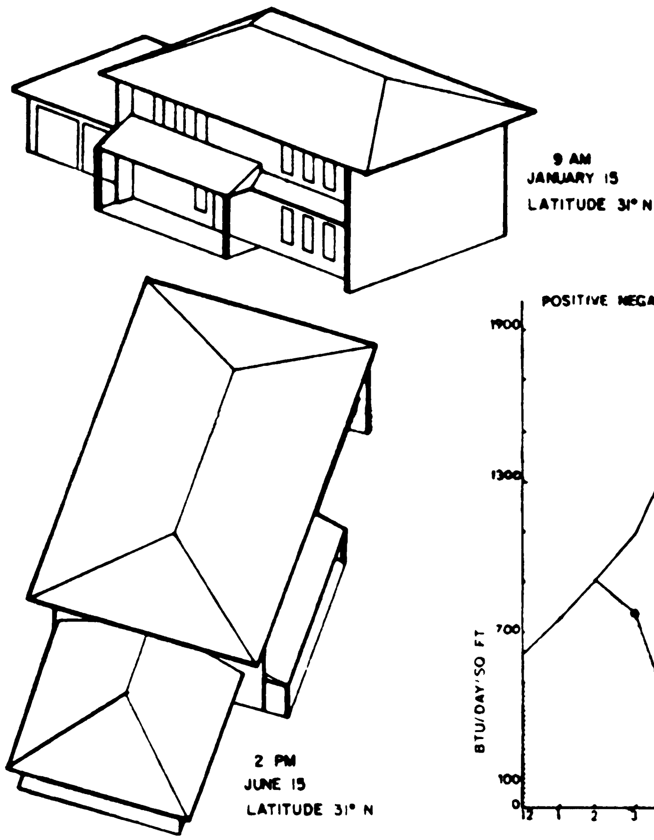
To determine the factors affecting energy consumption in a house, it is important to evaluate the designs that influence energy consumption and also evaluate the operation and maintenance of the house to determine what energy conservation methods may be employed to minimize energy usage (HUD, 1979).

Zimmerman and Hart (1982) cited three factors that offset higher fuel bills which must be included in a design. They are: (1) orientation of the house, (2) insulation to establish thermal quality, and (3) fenestrations and window areas to increase the amount of passive solar energy that can be used. These three areas are considered non-mechanical; however, they influence several other areas in the house which impact energy consumption that are considered mechanical; Dumas (1976); Gibbons and Chandler (1981); Burby and Marsden (1980); ASHRAE (1980); and Olin, Schmidt, Lewis (1980). These systems include heating, ventilating, cooling, hot water, lighting and other power systems used to meet the functional requirements of a house.

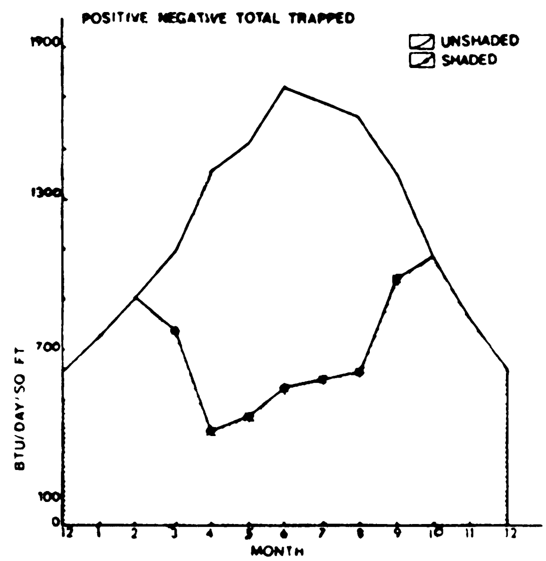
2.5.1 Orientation of the House

Dumas (1976) indicated the orientation of the house is the siting which provides for the maximum benefit gained through external and internal orientation. External orientation as stated by Dumas (1976) refers to the orientation of the house itself on the site as well as the arrangement of features of the house's thermal envelope. Internal orientation refers to the arrangement of the functional spaces within the house.

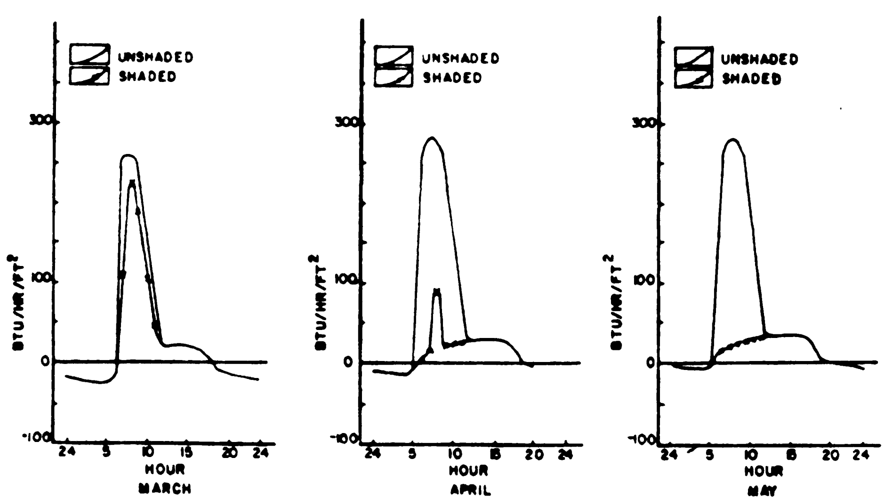
According to U.S. Department of Agriculture fact sheet (1978) external orientation relative to winds and sun can be critical to providing natural ventilation and lighting and to minimizing or maximizing solar gain. To allow the placement of a house on its site determined solely by the position of streets is only perpetuating mistakes of the past. Similarly, placement of windows and doors is too important to be determined solely on the basis of aesthetics (HUD, 1979). Watson (1979) indicated housing orientation impacts the amount of heat energy absorbed within the building. He stated heat gain can be a benefit to the house during winter months when heat loads are high or a detriment to the house during summer months when excess heat radiated through windows must be offset by air conditioning or shading. See Figure 2.7.



Winter and summer solar views of a house.



Daily heat gain through an east-facing window, with and without a fixed shading device.



Instantaneous rates of heat gain or loss through an east-facing window comparing the values when shading device is in place with values when not in place.

Figure 2.7 Effect of Building Orientation

Source: Watson, Donald, Energy Conservation Through Building Design, McGraw-Hill Book Company, New York, 1979 , p.49

2.5.2 Configuration of the House

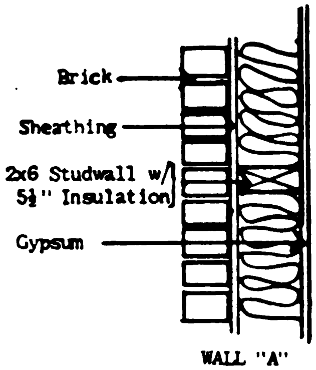
Zimmerman and Hart (1982) indicated the site, the climate, and the geographic location influence the energy absorption of the house. According to Coad (1976) the housing configuration should be designed to use the available energy systems that are most useful for a given locale. Sherwood and Hans (1979) indicate that the building mass, the relationship of the house to its surrounding (including local climate) and human comfort requirements are factors which influence residential design. According to HUD (1978) designers often use a rate of total square footage of exterior surface divided by the interior square footage of useful space as a criterion for evaluating the optimal configuration for housing design.

2.5.3 The Housing Envelope

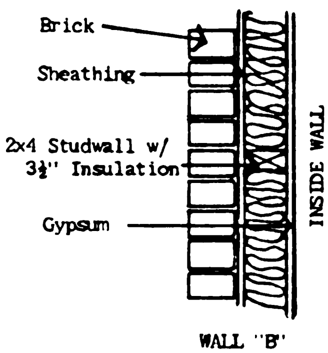
The building envelope includes walls, windows, doors, roof and floor surfaces that enclose and surround the building. According to Olin, Schmidt, Lewis (1980) and ASHRAE (1981) each of these surfaces is subject to different elements and has different thermal properties to resist heat transmission, see Figure 2.8 on comparative wall systems and Appendix E for thermal properties of materials. Figure 3.11 shows the differences in two types of wall systems and what effect increasing insulation has on the thermal resistance of a wall system. Wall system A has a total thermal resistance of 21.20 with 5 1/2 inches of fiberglass insulation compared with 14.80 for wall system B using only 3 1/2 inches of fiberglass insulation.

2.5.4 Fenestrations

Fenestrations are glass surface areas of a house. According to the Michigan Consumers Power Company, past homes typically have included window area equal to about 15 percent of the floor area. Reducing this to 10 percent, will reduce heat loss and not appreciably affect the appearance of the home (Consumers Power Company). Dumas (1976) indicated windows represent one of the most critical areas for the transfer of heat, light, and air between the building and its environment. Properly designed windows operate as valves which can be used to control the flow of energy between the internal and external environments. Zimmerman and Hart (1982) indicated new types and thickness of glass have now been developed which allow designers and builders to use glass materials more effectively without fear of energy loss. Insulated glass is now being used because it is low in conductive value (U value). Burby and Marsden (1980) cited reflective coatings, tinted glass, material thicknesses and double-pane construction now make glass and fenestrations an integral part of the building design. Tinted glass is normally used for its heat absorbing properties; whereas, reflective glass is used to reduce solar heat gains that increase cooling loads. In the make-up of the total building structure, the percentage of the surface



	Resistance
1. Outside air film at 15 MPH	0.17
2. 4 inch Brick	0.44
3. Sheathing	2.06
4. 5 1/2 inch Aluminum Foil Fiberglass Insulation	17.42
5. 2x6 Studwall @ 24' o.c.	-
6. Gypsum	0.45
7. Inside Film	0.66
Total R =	21.20



	Resistance
1. Outside air film at 15 MPH	0.17
2. 4 inch Brick	0.44
3. Sheathing	2.06
4. 3 1/2 inch Aluminum Foil Fiberglass Insulation	11.00
5. 2x4 Studwall @ 16" o.c.	-
6. Gypsum	0.45
7. Inside Film	0.68
Total R =	14.80

Figure 2.8. Example of Thermal Properties of Comparative Wall Systems.

Source: Thermal Properties of Building Materials, The Michigan Energy Code (Published by Energy Administration, Michigan Department of Commerce) 1981, pp. 22-26 area attributed to fenestrations needs to be taken into account in determining the heating and cooling loads for a home.

2.5.5 Lighting

Lighting systems serve as illumination sources for the house. According to Gibbons and Chandler (1981) lighting accounts for about 20 percent of all electrical demand. Thus important savings can come from unnecessary lighting. Zimmerman and Hart (1982) discussed the design of lighting systems using the foot-candle method and the point-by-point or task-lighting method. They discussed lighting evaluation criteria and noted task lighting greatly reduces total wattage requirements compared to broadcast lighting. Gibbons and Chandler (1981) cited that fluorescent lighting tubes provide three times more light per unit of energy consumed than incandescent bulbs, and further, the efficiency of lighting fixtures can be evaluated by determining the highest illumin output per watt. Both Zimmerman and Hart (1982) and Gibbons and Chandler (1981) stated that not only is the illumination factor important in lighting design but also the heat given off from lights as an added heat source. They noted that during the summer lighting can add .40 watts to an air-conditioning load for every watt of lighting. Gibbons and Chandler (1981) also discussed the new LITEK bulb which is a fluorescent light that is three times as efficient as the incandescent bulb yet shines in a gentle, broader spectrum with more natural light and works in incandescent sockets. Its cost is about $7.50 per bulb, has a payback period of about two years (assuming several hours of use per day) and has a life time of 10 years.

Dumas (1976) cited (see Table 2.3) the energy efficacies of selected artificial light sources from the Illuminating Engineering Society that incandescent lamps (whose energy output is about 90 percent heat and 10 percent light) are by far the least energy-efficient bulb.

Table 2.3 Energy Efficacies of Selected Artificial Light Sources

Source	Approximate Lumens per Watt
Incandescent	
40-watt general service	11.0
60-watt general service	14.3
100-watt general service	17.4
1,000-watt general service	22.0
100-watt extended service	14.8
Fluorescent	
two 24-inch cool white (approx. 20 watts each)	50
two 48-inch cool white (approx. 40 watts each)	67
two 96-inch cool white (approx. 112 watts each)	73
High intensity Discharge	
400 watt phosphor-coated mercury	46
1,000 watt phosphor-coated mercury	55
400 watt metal halide	75
1,000 watt metal halide	85
400 watt high-pressure sodium	100

Source: Compiled by the Illuminating Engineering Society, Architectural Graphics Standards, Seventh Edition, (Published by John Wiley and Sons, Incorporated, New York, New York, 1981), pp. 708-709

Fluorescent lamps are more efficient, providing 50-73 lumens per watt, while high intensity discharge are generally still more efficient.

Dumas (1976) also discussed the selected minimum levels of illumination as shown in Table 2.4.

Table 2.4 Selected Minimum Illumination Levels

Area or Activity	Minimum Recommended Footcandles
Residences	
Hallways, Conversational and Recreational Areas	10
Reading and Study Areas	30-70
Kitchen and Work Shop Activities	50-70
Prolonged or Finely Detailed Sewing	100-200

Source: Recommended by the Illuminating Engineering Society, Architectural Graphic Standards, Seventh Edition, (Published by John Wiley and Sons, Incorporated, New York, New York, 1981), p. 75

Overdesign of the lighting system will invariably lead to increased energy consumption. Stein in Dumas (1976) says lighting systems should be designed to maximize the use of natural lighting. Stein also says the lighting design should provide for an adequate level of general illumination along with supplemental, occupant controlled, specific task lighting (again see Table 2.4).

2.5.6. Heating, Ventilating and Air Conditioning (HVAC)

According to Gibbons and Chandler (1981), 65 percent of the total energy used in a building is used for space heating. Increasing the effectiveness of energy used for space heating is the most important energy conservation option within a home, (O'Callaghan, 1981). O'Callaghan (1981) examinations of existing housing systems showed that as much as 30 to 40 percent of the energy required for providing comfort control in buildings can be saved with more efficient design and control of operating equipment. In terms of energy-related costs, ventilation and thermal quality are areas that need concentration. As Stobaugh and Yergin (1979) stated, residential buildings are becoming even more "clever" in their use of energy. The equipment selected should have just enough capacity to maintain the desired comfort conditions as established in ASHRAE (1981) and the Michigan Energy Code (1981). If the equipment does not have the capacity to provide the comfort condition, it is undersized. The most common version, however, is to oversize the equipment; therefore, the equipment selected has more capacity to heat and cool than is required.

Oversizing equipment is more common than undersizing. There appeared to be three reasons for this. Black (1977) referred to the conservative or "be sure" design philosophy in sizing heating equipment which has developed over the years. Since the penalty for undersizing was greater than oversizing, oversized equipment was usually selected. Sherwood and Hous (1979) stated that the common use of oversized equipment was to compensate for building-design deficiencies. Dumas (1976) indicated that oversizing of equipment was due to the use of the "worst case" scenario.

For whatever reason the selection of oversized equipment occurs, the result has been a waste of resources and a sacrifice in the comfort conditions. Oversized equipment generally operates at reduced efficiency and requires more energy and materials to manufacture than equipment properly sized (Dumas, 1976).

ASHRAE (1981) provides the design criteria to control climate conditions within the structure. Olin, Schmidt, Lewis (1980) stated controlling the variations in temperature, relative humidity and air characteristics are the major parameters that influence system design. Controlling the interior environment, according to Olin, Schmidt, Lewis (1980), helps the body regulate its temperature and achieve the ideal comfort condition, a sensation that is neither too warm nor too cool.

ASHRAE Standard 55-74 established the thermal comfort envelope for new building design as shown in Olin, Schmidt, Lewis (1980) Figure 2.9 below.

Zimmerman and Hart (1982) stated the Americans have been accustomed to placing thermostats between 22.22 - 23.89^{o}C (72^{o} - 75^{o}F) for winter and anywhere between 18.33 - 21.11^{o}C (65^{o} - 70^{o}F) for summer. They also stated that during the

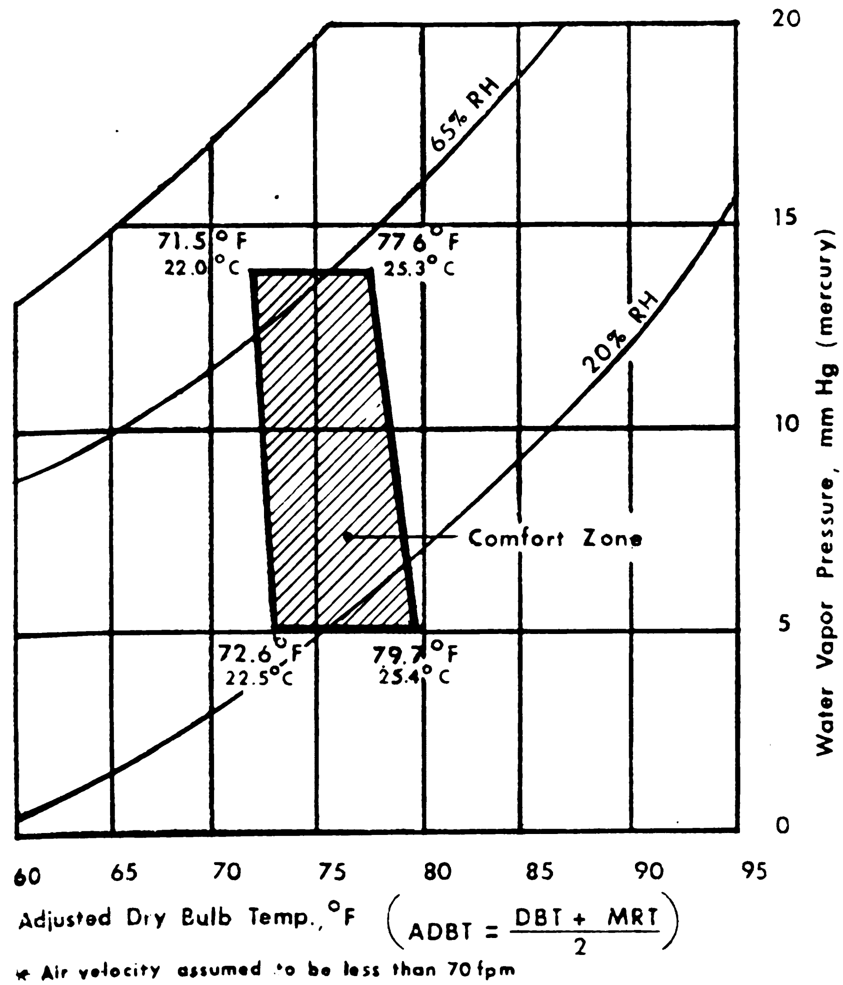


Figure 2.9 ASHRAE COMFORT ENVELOPE

Source: Architectural Graphic Standards, Seventh Edition, (Published by John Wiley and Sons, Incorporated, New York, New York, 1981), p.88

oil crisis of 1978-1979 the temperature levels were dropped during the winter to somewhere between 18.89°C - 20°C (66°F - 68°F) and as high as 25.56°C - 26.67°C (78°F - 80°F) with 60 percent relative humidity during the summer.

ASHRAE 90-75 permits the use of more energy-efficient environmental controls and it has a more realistic outlook on energy designs. It also takes into account the savings that can be made with minor changes in comfort levels that people have become accustomed to.

The type of control in a residential system used to regulate heating, ventilating and cooling operations can greatly influence the energy usage (ASHRAE, 1980). The controls can be direct or indirect. Direct controls supply the need for energy at the rate required to fulfill the energy needs (Watson, 1979). An example of a direct control would be a simple thermostat, which senses the need for additional heat or cooling and turns the equipment on or off at the appropriate time and gives the level of temperature desired. Indirect controls are building components that are energy users in which the amount delivered or consumed is not related to the need within the residence. An example, as Dumas (1976) stated, is designing energy systems for the worst case (peak energy use) to satisfy the most extreme condition. However, the system operates at peak-design conditions throughout the life of the structure resulting in an extreme amount of energy being consumed.

Zimmerman and Hart (1982) stated the American's per capita consumption of energy is 10 times higher than the average of the rest of the world and a major part of this has come from the comfort level enjoyed in our buildings and residential homes.

The objective today, is to design a building that consumes less energy and at the same time does not sacrifice comfort, (O'Callaghan 1981).

3. METHOD

3.1 General

The present study utilized a qualitative comparative analysis approach to obtain the results. The study followed a similar study completed by Burby and Marsden (1980) University of North Carolina, Chapel Hill.

The qualitative approach was selected because it is useful in a preliminary study of this kind. Major insights can be identified for later studies utilizing random sampling and statistical methods.

Qualitative methods seek to obtain descriptions while quantitative methods seek to obtain data in numerical form for the purpose of testing for statistical significance. The distinguishing feature between the two methods is the character of how the data are collected rather than the numerical analysis performed after the data are collected.

Qualitative methods obtain data which are focused and topical and depend on the study to shape the comparison framework. Some prominent examples of qualitative methods include open-ended interviews, case studies, public hearings and community forums. The researcher selected open-ended interviews as the means for obtaining the data base used in this study. (For extensive discussion about the two methods, see Patton (1980) and Cook & Reichardt (1979).)

The open-ended interview does not have a rigid format to structure the interaction between the interviewer and respondent. However, questions are used and the interviewer uses the same questions for all respondents in order to obtain a comparison, thus a certain amount of predetermined structure is present. However, the interviewer is not limited to predetermined "probe" questions.

The interviewer can explore interesting ideas and concepts with the respondent as they occur naturally during the conversation and can enjoy immediate feedback. These are the major strengths of an open-ended interview.

With these major strengths, the open-ended interview also contributes two major weaknesses. When using open-ended interviews, the biases of the interviewer may easily become inseparable from data collected unless precautions are taken. (Such precautions might be some type of coding of the responses.) Secondly, the data obtained may be more difficult to analyze over results obtained by quantitative methods.

3.2 Overview

This study was conducted in Greater Lansing, a community in South Central Michigan, which includes the Cities of Lansing, East Lansing, Haslett and Okemos.

Greater Lansing is a moderate-sized community with a population of about 200,000. The community is dominated by three large organizations: Michigan State Government, Oldsmobile Division of General Motors, and Michigan State University. Climatically, the area is similar to north central communities, with moderately severe winters and mild summers.

3.3 Identification Interviews With Home Builders

3.3.1 Sample

Fifteen home builders were interviewed for the research project from the Greater Lansing area. Help was obtained from professional organizations, researchers, the phone book yellow pages and newspaper classified ads to identify builders that advertised energy efficiency, as compared to those that did not. The researcher identified and interviewed the individuals within the firms who were the most interested and knowledgeable about energy efficient features, or the one who made the decisions to include or not include certain features. The initial contact was made by telephone and interviews were then scheduled.

After conducting six interviews, the researcher realized the assumption of finding builders who were not as energy conscious compared to very energy conscious builders in equal numbers, was not holding true. All of the first six interviews turned out to be very energy conscious, so the researcher had to continue interviewing to find somewhat equal numbers for comparison. All the builders in this study were considered energy-conscious builders yet, some builders were considered more energy conscious than others.

In this project the researcher placed the builders into two groups, those considered very energy conscious (Group A) and those considered not as energy conscious (Group B), and determined what comparative factors might have caused builders to make certain decisions concerning energy features in each group. Builders were placed in (Group A) if they: were concerned about energy conservation; were knowledgeable in heat-loss calculations; and utilized the energy features in their most recent home to support their decisions and intentions.

3.4 Procedure For Conducting The Interview

The procedure utilized for conducting the interview was a series of questions which were used as a guide to obtain comparable information from the home builders and to allow the researcher to explore "other" relevant leads. The interviews averaged 45 minutes in length. The same open-ended questions were asked all home builders. However, different follow-up questions were used for different home builders at the discretion of the researcher. Nine of the interviews were conducted at the home builders site and six of the interviews were conducted at the Meridian Mall Home Builders' show. At the beginning of the interview, the researcher went through an introduction to the project and covered an overview of the questions which would be asked. During the interview, notes were taken according to the information received. The first interview was conducted 21 February 1983 and the final interview was conducted 24 March 1983. A summary interview guidesheet of questions appears in Appendix F.

3.5 Assumptions

3.5.1. That open-ended interviews would elicit the necessary data for a qualitative comparison between very energy conscious and not as energy conscious home builders.

3.5.2. There are builders who are energy conscious and builders that are not as energy conscious.

3.5.3. There were reasons for including or not including certain energy features in housing designs.

3.5.4. The individual interviewed knew the firm's techniques and way of construction.

4. RESULTS AND DISCUSSIONS

4.1 Overview

All the data collected in this study consisted of responses to open-ended questions. These responses were categorized to produce an aggregated frequency. No statistical techniques were employed to analyze the results. Only frequency counts are used for the qualitative/descriptive analysis.

4.2 General

Construction is the largest industry in the United States, which accounts for 10 percent of the nation's gross national product, (Burby and Marsden, 1980), and housing construction represents about one-third of new private construction and about one-quarter of all new construction.

Home builders represent a large portion of the construction industry and are the firms which produce finished housing for sale to the public. They act as general contractors and negotiate contracts with subcontractors for the myriad of tasks required for construction.

Burby and Marsden (1980) stated that with the size and complexity of the home-building industry there are two inherent problems concerning energy conservation. First, energy conservation must be designed to affect all the individuals involved in the industry. It is different from the automobile industry where promotion of energy-efficient features can be achieved by changing the behavior of one, two or three companies. Second, with the myriad of subcontractors involved, no group or firm by itself is totally responsible for the adoption of energy conservation practices and features.

4.3 Type of Firms

The firms researched in this study were both merchant and general contract builders combined. Merchant builders (sometimes called speculative builders) build houses to their own design specifications, on their own land, for sale or rental to others. Whereas, general contractors (sometimes called custom builders) build on land owned by others, usually according to plans provided by the owner. All the firms interviewed in this research engaged in speculative construction and general contract construction. After interviewing the builders, it was found that builders who build speculative houses have more of a direct influence on energy efficiency in the houses they build compared to houses built by a general contractor. Therefore, the decisions of a speculative builder had more of an effect on energy conservation features and efforts utilized than decisions made by general contractors which build to specifications provided by the owner.

4.4 Home-Building Firm Characteristics

Objective 1). Determine if any builder characteristics might have an effect on the use of energy-efficient features in new construction.

The home-building industry is noted for having small firms and in this project 80 percent of the builders (12 out of 15) constructed fewer than 24 homes last year (1982), (see Table 4.4.1) and had nine or less full-time employees (see Table 4.4.2).

Table 4.4.1 Number of Housing Units Constructed in 1982

# of Units	Group A	Group B
1-4	2	2
5-9	1	2
10-14	1	1
15-24	2	-
25-49	2	-
50-99	1	1
100 or more		
Total	9	6

Table 4.4.2 Number of Employees Employed Full or Part-Time in 1982

# of Employees	Group A	Group B
3 or less	2	3
4-6	4	-
7-9	-	3
10-19	2	-
20 or more	1	-
Total	9	6

Four out of 15 (27 percent) were considered medium builders, building between 25 and 99 homes and employed between 10 and 20 plus full-time or part-time employees.

The success of the small builder was determined to be due to the dispersed character of the market between subdivisions, as well as, being familiar with the local housing preferences and market conditions. Another reason for the small builder's success has been the unstable character of the housing industry with sharp changes in demand, which has encouraged firms to avoid large fixed overheads. Between Group A and Group B, in this study, Group A tended to construct more houses last year and employ more employees.

Instead of employing a large number, home building firms subcontract a large number of the building operations to special trade contractors or subcontractors.

4.5 The Home Building Firm Executives

Most of the firms interviewed were structured in such a way that the decision-making authority was centralized, which made it easy to talk to the executive responsible for energy related decisions.

The characteristics of the interviewed executives concerning age, education, experience in home building and attitudes toward energy policies are summarized in Table 4.5.

Table 4.5 Selected Characteristics of Home Building Executives

Characteristic	Group A	Group B
1. Age		
under 35	4	2
35 - 44	4	3
45 - 54	1	1
55 or older	-	-
2. Education		
less than high school	-	-
high school graduate	-	-
some college	3	2
college graduate	5	4
graduate degree	1	-
3. Experience in Home Building		
less than 10 years	4	1
10 - 19 years	3	4
20 or more years	2	1

4. Attitude toward Energy and Policy	Very Concerned		Concerned	
	Group A	Group B	Group A	Group B
a. Energy Conservation	8	-	1	6

	For		Opposed	
	Group A	Group B	Group A	Group B
b. Incentive policies to promote conservation i.e., tax rebates	9	6	-	-
c. Pricing policy to discourage energy usage i.e., increase the cost of heating fuels	-	-	9	6
d. Regulatory policies i.e., requiring disclosure of annual heating and cooling costs.	-	-	9	6

There were no meaningful differences between age and education between Group A and Group B. Concerning experience in home building, Group A's interviewed executives tended to have less experience. Forty-four percent of Group A builders (4) had less than 10 years experience compared to 17 percent for Group B. Between both groups 40 percent (6 out of 15) were under age 35 and 47 percent (7 out of 15) were between 35 and 44 years of age. Only 13 percent (2 out of 15) were 45-54 years of age. Most of the individuals interviewed had some college or were college graduates. Thirty-three percent (5 out of 15) did not have a college degree.

Of the individuals interviewed who had less than 19-years experience in home building, 33 percent (5 out of 15) had less than 10 years and 47 percent (7 out of 15) had between 10-19 years experience. Twenty percent (3 out of 15) had more than 20 years experience in home building. There was one major difference noticed in attitudes toward energy policy between Group A and Group B. Group A tended to try to save as much energy as they could to help the consumer have as low as utility bills as possible. Whereas, Group B did not place energy as one of their highest priorities.

Both groups agreed that incentive policies to promote energy conservation, i.e., tax rebates, were good. Whereas, the groups opposed pricing and regulatory policies to discourage energy usage. Both groups thought the less the regulation the better off the home-building industry.

4.6 Use of Subcontractors

Table 4.6 shows a summary of the home builder's use of subcontractors to perform key construction operations. All the home builders used their own employees or employees with subcontractors for only one of the eight tasks, marketing and sales, and all the builders subcontracted electrical work. Whereas 93 percent (14) subcontracted plumbing, 80 percent (12) subcontracted heating, ventilation and air conditioning, 67 percent (10) subcontracted grading the lot, and landscaping, and 60 percent (9) subcontracted framing, and insulation.

In comparing Group A and Group B, Group A tended to have more of their own employees and subcontractors working together, whereas Group B tended to have most of the work performed solely by the subcontractor.

The practice of subcontracting is important when it concerns the installation of energy conservation features. If every policy was effective in motivating the builder to increase the energy efficiency of the houses they build, some questions still exist as to how much control the builder has over the construction process when subcontractors are used and when monitoring energy efficiency is concerned.

4.7 Responsibility for HVAC and Insulation Decisions

In order to determine how much control the builder has over energy-efficient features, the researcher asked who has the responsibility for decisions about heating, ventilating

Table 4.6 Use of Subcontractors to Perform Selected Home Building Operations.

Operation	Task By Own Employees		Task By Own Employees And Subcontractors		Task Performed By Subcontractor	
	Group A	Group B	Group A	Group B	Group A	Group B
Electrical work	-	-	-	-	9	6
Framing	2	2	2	-	5	4
Grading the lot	2	-	1	2	6	4
Heating Ventilation & air conditioning	-	-	3	-	6	6
Insulation	3	1	2	-	4	5
Landscaping	2	1	2	-	5	5
Marketing & Sales	6	6	3	-	-	-
Plumbing	-	-	1	-	8	6

and air conditioning (HVAC) and decisions concerning installation of insulation? In HVAC systems, two areas are considered important: (1) the type of heating system used, i.e., gas, oil or electric; and (2) the capacity of the system, whether it will meet or exceed design requirements. The results are summarized in Table 4.7

Table 4.7 Responsibility for Decisions about Heating, Ventilation, and Air Conditioning Systems (HVAC) and Installation of Insulation.

HVAC SYSTEMS	Builder Specifies		Joint Decision		Subcontractor Specifies	
	Group A	Group B	Group A	Group B	Group A	Group B
1. Type of Heating System Used	4	1	5	3	-	2
2. Capacity of Heating Equipment	3	1	4	1	2	4

INSULATION	Builder Specifies		Joint Decision		Subcontractor Specifies	
	Group A	Group B	Group A	Group B	Group A	Group B
1. Type of Insulation	7	5	2	1	-	-
2. Amount of Insulation	7	5	2	1	-	-

Group A builders tended to specify or have joint decisions in determining type and capacity for HVAC system. Out of Group A, 44 percent (4 out of 9) specified the type of heating system and 56 percent (5 out of 9) had a joint decision. Whereas in Group B the decision tended to favor the subcontractor who specified the capacity of the system.

For insulation the builders tended to have a greater role in decision making. All the builders specified or had a joint decision in type and amount of insulation used. No difference was noted between Group A and Group B concerning insulation.

From what is shown here, policies and programs designed to promote the use of adequate amounts of insulation in the home-building industry should be directed toward the builder. For HVAC systems, policies and programs designed to promote energy-efficient systems should be directed at both the home builder and the HVAC contractor to insure systems are properly matched to need.

4.8 Recent Housing Characteristics

To this point the researcher covered the individuals interviewed. The next series of questions concerned the characteristics of the most recent house the builder constructed, where they were responsible for the characteristics of the house built. The researcher initially wanted data on speculative homes, but when the builders were asked if they built speculative homes last year only one out of 15 builders had.

The data collected were from recent houses built where the builder was responsible for selected energy features. The housing data on Table 4.8 includes the style, size, price and selected basic features of the house.

Table 4.8 Characteristics of the New Recent Houses Built

	Group A	Group B
Housing Style		
one story ranch	7	1
split level	-	-
two story	1	5
three story	-	-
other (two story earth sheltered)	1	-
Sizes of the Houses		
under 116.13m^2 (1250 SF)	4	1
116.13m^2-139.26m^2 (1250SF-1499SF)	1	1
139.35m^2-162.48m^2 (1500SF-1749SF)	3	1
162.57m^2-185.71m^2 (1750SF-1999SF)	1	-
185.8m^2 or more (2000SF)	-	3
Prices of the Houses		
under $35,000		
$35,000-$44,999	2	-
$45,000-$54,999	3	1
$55,000-$64,999	-	1
$65,000-$79,999	2	-
$80,000-$94,999	-	2
$95,000-$124,999	2	1
$125,000-$149,999	-	-
$150,000 or more	-	1
Features Utilized		
range hood with fan	9	6
two or more bathrooms	4	3
central air conditioning	3	2
fireplace	5	5
dishwasher	8	4
separate family room	4	3
separate dining room	4	4
patio or deck	6	5
garage	8	6
garbage disposal	7	6
bathroom heater	2	1
trash compactor	-	-
enclosed/screened porch	-	3
microwave oven	2	2
central vacuum system	-	1

Within the builders of Group A, 78 percent (7 out of 9) constructed a one-story ranch as their most recent house. The size of Group A homes tended to concentrate in two sizes, under 116.13m^2 (1250SF) and between 139.35m^2 (1500SF) and 162.48m^2 (1749SF), with no house over 185.8m^2 (2000SF). The price of Group A homes did not seem to concentrate within any area, the price ranged from $35,000 to $125,000.

For Group B, five out of six builders constructed a two-story style house which is considered to be more energy efficient since less roof surface area is exposed to theelements per square meter or square foot of floor area. The sizes of Group B houses tend to be somewhat larger with three of six houses over 185.8m^2 (2000SF), and Group B's prices tended to be higher, with four of their houses over $80,000.

With the basic features utilized in the houses, there were no noticeable differences between either group. The following percentages will be totals between the two groups. Sixty-seven percent of all the builders (10 out of 15) used fireplaces which have a potential to increase fuel consumption, rather than decrease. The number of features that a builder puts in his houses will show some indication of the amount of energy usage within the house. Home builders are installing a number of appliances which are energy consumption related, i.e., 87 percent (13 out of 15) of the builders installed garbage disposals and 80 percent (12 out of 15) installed automatic diswashers, whereas only 27 percent

(4 out of 15) installed energy efficient microwave ovens. Thus, home builders are responding to consumer demands by installing energy consumption features within the most recent houses constructed.

4.9 New Home Energy Efficient Features

A list of energy efficient features utilized for obtaining data from the builders is listed in Table 4.9. The top portion contains certain features aimed at improving the efficiency of the heating and cooling system. These include the type of equipment, the controls and supplementary heating (wood stoves) which must be taken into consideration in order to match the heating and cooling loads for a certain location.

The bottom half of Table 4.9 examines features that improve the thermal performance of the house. This focuses on reducing heat loss or gain through the shell of the house, i.e., walls, ceilings, doors, windows and other openings.

Between Group A and B there was little difference in the heating/cooling equipment features used; however, 20 percent of the Group A builders installed wood stoves, pulse high-efficiency furnaces and air-to-air heat exchangers. In summarizing the heating and cooling features both groups have adopted (100 percent, all 15 builders) heating/cooling systems closely sized to match design loads, 100 percent (15 builders) used some type of attic, roof or ridge ventilation

Table 4.9 Conservation Features of the Most Recent House Built.

Heating/Cooling Equipment Features	Group A	Group B
1. Heating and cooling system closely sized to match design loads	9	6
2. heat pump heating and cooling system	-	-
3. attic, ridge or roof ventilation	9	6
4. clock thermostat on heating/cooling system	6	3
5. wood stove	3	-
6. solar hot water heating	1	-
7. active solar space heating	-	-
8. pulse high efficiency furnace	3	1
9. air to air heat exchanger	3	1
10. paddle ceiling fans	1	-
11. vent damper (FLUE)	2	1
Construction features affecting the houses heat loss/gain		
1. storm windows/double glazed windows	9	6
2. square or rectangular shaped house	9	6
3. insulated ceiling access panel	7	5
4. insulation exceeding building code standards	9	6
5. glass area 10% or less of floor area	8	3
6. landscaped lot with deciduous trees for summer shade	1	2
7. fireplace which uses outside air for combustion	6	3
8. insulated hot water pipes	1	-
9. 76.20 cm (30 inch) roof overhang for summer shade	6	1
10. passive solar heating using a maximum of south-facing glass	7	1
11. 5.08 cm x 15.24 cm (2 x 6) framing for extra insulation	5	-
12. reflective glass	-	-
13. insulated shutters	2	-
14. earth sheltered or earth bermed	2	-
15. super insulation	2	-
16. envelope construction	1	-
17. styrofoam exterior wall sheathing	9	6
18. double infiltration/vapor barrier	2	-
19. energy trusses	5	-

and 60 percent (9 out of 15) used clock thermostats on heating/cooling systems.

In looking at the thermal performance data, (100 percent, 15 out of 15) builders used storm windows/double glazed windows, square or rectangular-shaped houses, insulation exceeding building codes of the Michigan Energy Code (R20 in ceilings, R5 in walls, R12.5 for floors over unheated spaces), and used styrofoam on the exterior walls. Eighty percent (12 out of 15) were insulating the ceiling access panels and 73 percent (11 out of 15) have a glass area of 10 percent or less of the floor area. Group A builders have tended to use more features than Group B, especially with 76.20cm (30 inch) roof overhang, passive solar heating from south-facing glass, 5.08cm x 15.24cm (2" x 6"), framing for extra insulation in the walls, and energy trusses also for extra insulation in the ceiling.

The data show all the builders interviewed are producing energy-efficient houses; however, Group A tended to use more features per house than Group B.

4.9.1 Added New Features

When asking the builders what features they would add to the next house, 33 percent (3 out of 9) of Group A builders said they would use 5.08 cm x 15.24 cm (2" x 6") framing for extra insulation in the walls, and use a wood basement. Group A builders tended to select or use a few more features than Group B, but the predominant observation between all

Table 4.9.1 Conservation Features Most Likely to be Added to the Next House if Conditions Warranted a more Energy-Efficient House.

Heating and cooling equipment features	Group A	Group B
1. Heating and cooling system closely sized to match design loads	-	-
2. heat pump heating and cooling system	1	-
3. attic, ridge or roof ventilation	-	-
4. clock thermostat on heating/cooling system	-	-
5. wood stove	-	-
6. solar hot water heating	-	-
7. active solar space heating	-	-
8. pulse high efficiency furnace	-	-
9. air to air heat exchanger	1	-
10. paddle ceiling fans	-	-
11. vent (flue) damper	-	-
12. masonry wood stove	1	-
Construction features affecting the house's heat loss/gain		
1. storm windows/double glazed windows	-	-
2. square or rectangular shaped house	-	-
3. insulated ceiling access panel	-	-
4. insulation exceeding building codes	-	-
5. glass area 10% or less of floor area	-	-
6. landscaped lot with deciduous trees for summer shade	-	-
7. fireplace which uses outside air for combustion	-	-
8. insulated hot water pipes	-	-
9. 76.20 cm (30 inch) roof overhang for summer shade	-	-
10. passive solar heating using a maximum of south facing glass	-	-
11. 5.08 cm x 15.24 cm (2" x 6") framing for extra insulation	3	2
12. reflective glass	-	-
13. insulated shutters	-	-
14. earth sheltered or earth bermed	1	-
15. super insulation	-	-
16. envelope construction	-	-
17. styrofoam exterior wall sheathing	-	-
18. double infiltration/vapor barrier	-	-
19. energy trusses	-	-
20. blown in cellulose for walls	-	1
21. closed in (air tight) vetibule	2	-
22. energy trusses	2	-
23. wood basements	3	-
24. insulate basement	2	1

the builders is that they would not adopt any one particular feature next. None of the builders selected active solar features, reflective glass or insulated shutters and only one selected a heat pump heating and cooling system. Table 4.9.1 shows features to be added to the next houses constructed if conditions warranted a more energy-efficient residence.

4.10 Response for Energy-Efficient Features

Objective 2) Determine what might stimulate builders to consider putting energy efficient features into a new residence

When the researcher asked the builders what stimulated them to consider putting energy-efficient features into a new residence, the general response between both groups centered around consumer demand and high costs of energy as shown in Table 4.10.

Table 4.10 Stimulated Response for Energy-Efficient Features

Response	Group A	Group B
Consumer Demand (marketing)	2	5
High costs of energy	4	-
Energy resource shortage	1	-
Code requirements	1	1
Knowledge and awareness	1	-
Other secondary concern - qualify more buyers	1	-

Forty-four percent of Group A builders (4) chose high costs of energy and 83 percent of Group B builders (5) chose consumer demand. The other responses included energy resource shortages, code requirements, knowledge and awareness and a secondary item of concern: being able to qualify more home buyers.

The builders responded they did not look at energy conservation features as being an innovation to expand their present market, but as a way to maintain adequate sales of the houses they presently build for their own markets. The factors of high costs of energy and consumer demand (marketing) were very closely linked between the two groups. In terms of high energy costs/consumer demand, the builders responses were concerned costs which the customer is willing to pay, operating expenses, and the savings the consumer is looking for by installing energy-efficient features. The builders also responded that these two areas were key factors in determining whether to include energy conservation features in their most recent house built.

4.11 Perceived Consumer Resistance

Objective 3) Determine builders' estimates of the most important reasons for consumer resistance to energy-efficient features.

When asking the builders their estimates of the most important reason for consumer resistance to energy-efficient features, 67 percent (10 builders, 4 from Group A, 6 from Group B) cited costs as the most important reason (shown in Table 4.11).

Table 4.11 The builders' estimates for the most important reason for consumer resistance to energy-efficient features.

Responses	Group A	Group B
- cost		
--uncertain about savings in operating costs	2	1
--not willing to pay for extras even if they save money	2	2
--payback time is too long	-	3
- consumers are not resistant	3	-
- too conservative about new products/ designs	1	-
- different from old traditional way of construction and aesthetics	1	-

These builders state the most important reasons for consumer resistance to energy-efficient features comes from buyers, that were: leery of the amount of savings generated in utility bills, or unwilling or often unable to pay even if it would save money in the long run, or have questions concerning the payback time. Other factors stated by builders as reasons for consumer resistance to energy-efficient features were: construction techniques or designs which are different from the old traditional way of construction or aesthetics. These consumers liked the old high ceilings with plenty of windows and were not really concerned about utility costs and did not like the looks of the new modern designs for energy efficiency.

In comparing Group A and Group B, there was a slight difference in the responses, 33 percent (3 out of 9) builders in Group A stated consumers are not resistant to energy features and 50 percent of Group B (3 out of 6) stated payback time is too long. Group A's response was based on the idea that when you adequately justify costs versus expenses saved, the consumer does not resist, whereas Group B states it takes too long to get back the initial cost of most energy-efficient features.

In the selection of cost-effective energy-conserving features for new homes, builders have to answer the question: What features will achieve the best results for the least cost?

The answer may sound simple, but it is quite complex when variables such as local climate, type and size of house, cost of energy, type of energy, type of HVAC system, design details and the level of thermal protection are included. It was found in this study that five builders (all Group A), utilized a service provided by heating and cooling contractors or professional organizations which use a computer-analysis technique to determine energy cost savings or payback time to recoup an investment. The rest of the builders utilized their own cost-benefit analysis or payback method for their determination. The problem with the cost-benefit analysis or simple payback method is, they do not take into account the increase in the price of energy or the mortgage interest rate compared with the preferred life-cycle cost method (an example is shown in Appendix G).

4.12 Criteria for Making Final Decision

Objective 4) Determine the criteria the builder might use in making a final decision to use an energy-efficient feature.

The builders were also asked what criteria might be used in making the final decision to include or not include an energy feature in a new residence. Forty-four percent, 7 builders (4 Group A, 3 Group B), picked consumer demand, interest, acceptance (marketability) as the most important reason in making the final decision, and 47 percent of the builders (4 Group A, 3 Group B) chose performance reliability/inherent energy efficiency as the most important criteria, as shown in Table 4.12.

Table 4.12 Criteria a builder might use in making a final decision to use an energy-efficient feature.

Responses	Group A	Group B
performance reliability/inherent energy efficiency	4	3
consumer demand	4	3
installs energy efficient features initially where buyer would not be able to add later	3 (2)	-

other items mentioned
- ease of installation
- willingness/unwillingness of sub-contractors
- cost in comparison with alternatives

---

(2) stated along with consumer demand

The only difference noticed between the two groups here, one-third of the Group A builders stated they also base their final decision on whether or not the customer can install the item later. If the item cannot be installed later, it becomes an included feature in the initial construction.

4.13 Risks Involved in Using Energy Features

Objective 5) Determine the risk factors involved in using energy-efficient features in new construction.

Another way or method of analyzing the builders' decisions is to look at the risks involved in using energy features. Five risks were placed on separate slips of paper and these slips were handed to the builders. They were then asked to rank them in order of importance: most serious on the top to least serious on the bottom. In analyzing the results, 33 percent of all the builders (5), all Group A builders, listed problems in getting features properly installed as the most important risk (shown in Table 4.13), followed closely by difficulty in selling the house (marketing) and having to respond to consumer complaints after the sale. The risk that emerged as the second most important was incurring higher costs than expected, 40 percent (6 builders, 4 Group A, 2 Group B) chose this.

In comparing Group A and Group B, 50 percent (3 out of 6) Group B builders chose difficulty in selling the home as the most important risk. This was different from Group A's

Table 4.13 Risk factors involved in using energy efficient features for new construction.

	Most Imp.	2nd Most Imp.	3rd Most Imp.	4th Most Imp.	5th Most Imp.
Problems in getting features properly installed	5	3(2)	6(3)	-	(1)
Incurring higher costs than expected	2(1)	6(2)	5(2)	-	2(1)
Having to respond to consumer complaints after the sale	4(2)	4(1)	2	(3)	2
Delay in getting the house completed	-	2(1)	(1)	9(2)	3(2)
Difficulty in selling the home	4(3)	-	1	3(1)	7(2)

( ) = Group B response

response, which was, problems in getting features properly installed.

In summarizing Table 4.13 Group A chose problems in getting features properly installed. This response is supported by the results on Table 4.4.1, where Group A tended to construct more houses, Table 4.8 where Group A tended to construct smaller one-story ranch and less expensive houses, and Table 4.7, where Group A tended to install more energy features per house than did Group B.

With the increased number of features Group A installs (linked with cost and marketing), the competition becomes greater as the price of the house comes down, along with having features properly installed. Group B's most important risk, (difficulty in selling the house), also is supported by other data. Group B built fewer homes; Table

4.4.1, and built larger two-story, more expensive homes than Group A, Table 4.6, which placed Group B in a different market. Difficulty in selling the house then becomes their most important risk in maintaining sales.

4.14 Steps for a Tighter Home

Objective 6) Determine what the builders' suggested steps are to insure a tighter more energy-efficient home.

After researching the decisions about energy features, the researcher then focused on what steps the builder goes through to insure a tighter, more energy-efficient home. All the builders knew the Michigan Energy Code was required by law and not just recommended and all answered correctly that cutting infiltration in and around and through windows and doors was the area of greatest heat loss. Yet even with this knowledge, it was found Group B builders tended to use less energy features in their new homes than Group A, as was shown in Table 4.9. It was also evidenced through the interviews that the stronger the attitude the builder had toward energy conservation, especially noticed in Group A, the more likely they were to use energy-conserving features.

The following list shows aggregate response by the builders when asked, "What steps might you take to insure a tighter, more energy-efficient home?

- Reduce air infiltration by taping, caulking, weatherstripping and using foam insulation around windows and doors.
- use an infiltration barrier on outside walls along with vapor barrier on inside walls.
- caulk and seal every penetration on the outside walls and ceilings.

- using fewer windows and storms with double or triple glazing.
- inspect the work to insure good tight construction.
- insulate the basement.
- use storm doors with insulated doors.
- closed-in vestibule.
- add more insulation to walls or attic (5.08 cm x 15.24 cm (2" x 6") framing or energy trusses).
- use quality products.
- Outside air for fireplace.

Most of the responses from the builders focused on cutting down infiltration through and around windows and doors, caulking, weatherstripping and putting insulation around them, as well as, using a smaller number of better-constructed windows and doors. A number of the builders commented: the quality of construction in the way the features are installed; the care in how the house is framed and amount of insulation, must be considered equally important in reducing infiltration.

Between Group A and Group B builders, Group B tended: to use less infiltration/vapor barrier material (i.e., no vapor barriers in the ceilings), stuff insulation around windows and doors rather than use foam insulation, tended not to tape styrofoam wallboard seams, were generally satisfied with the tightness of their construction and finally, felt further steps were not needed. Whereas, Group A tended to be continually striving for a tighter more energy-efficient home.

While the care in and quality of construction (how the house is framed and insulated) was found to be one barrier the builders have in building a tighter more energy-efficient home, the builders also identified others.

4.15 Obstacles to Building an Energy-Efficient Home

Objective 7) Determine what obstacles the builder has in building an energy-efficient home.

When asked what obstacles the builders might have to building energy-efficient homes, 73 percent (11 builders, 5 Group A, 6 Group B) chose either cost or marketing as the primary obstacle as shown in Table 4.15.

Table 4.15 Obstacles the builder has in building an energy-efficient home.

Responses	Group A	Group B
- cost or marketing	5	6
- obtaining knowledge and technical proficiency on energy-conservation features	3	-
- supervision and subcontractors performing high quality work	1	-

Twenty percent of the builders (3 out of 15 which were Group A builders) responded that obtaining knowledge and technical proficiency of new energy-conservation features as their primary obstacle. One builder responded getting subcontractors to perform high-quality work was their biggest obstacle.

4.16 Insulation Values of Ceilings and Walls

Objective 8) Determine if builders will cut insulation to save costs and determine dollar amount added to the monthly mortgage payment versus dollar amount in savings to the buyer.

Cost and marketing has been shown to be a predominant response to using or not using energy-efficient features through the entire study. With costs and marketing being so important, would builders then cut insulation to save costs? Figure 4.1-4.2 show the approximate R-values of the walls and ceilings of new houses. It appeared that builders tended not to cut insulation to save costs. However, Group A builders tended to use more insulation in the ceilings and walls compared to Group B.

4.17 Dollars Energy Features Add to Monthly Mortgage Payment

The last question asked of the builders was concerned with the amount of money the energy features would add to the monthly mortgage payment versus the amount of money saved. Only 11 of the builders responded to this question (7 Group A, 4 Group B). Because it was difficult to justify the numbers from the builders' response without going through their files, the researcher utilized the numbers of the responses, totaled them, then divided the total by the number of builders in each group to come up with an average figure. The average cost of energy features for Group A

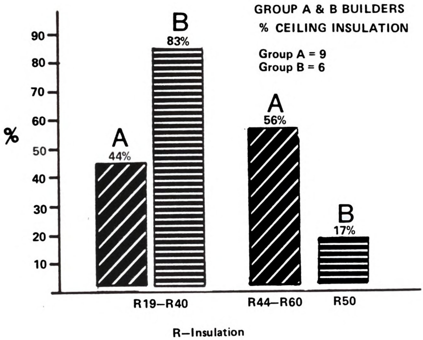


Figure 4.1 Ceiling Insulation Value

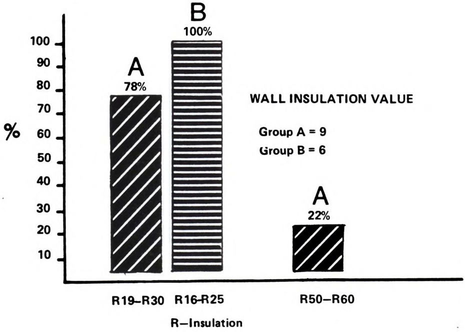


Figure 4.2 Wall Insulation Value

builders that responded equaled $3,263.43, and for Group B $2,925.00 for a difference of $338.43. Group A tended to spend more money on energy features than Group B, which supports the information in Table 4.9.1 which indicated Group A tended to use more energy features than Group B.

Using a 14-percent monthly compounded interest rate and a 30-year loan amortization, Group A builders' energy features would add $38.67 per month to the mortgage payment compared to $34.66 per month for the Group B builders.

In comparing these figures with the results from a survey completed in September 1981 by Professional Builder Magazine, the above figures are close to their findings, as shown in Figure 4.3.

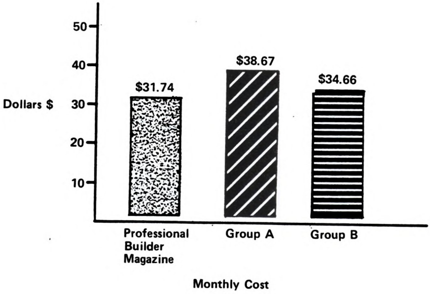


Figure 4.3 Average Cost per Month for Energy Features.

Finally builders were asked to estimate the amount of savings in utility bills the investment in energy-saving features would generate. The builders just did not have enough information back on the houses they have built, or they just did not know.

5. SUMMARY AND CONCLUSIONS

5.1 Summary

From the qualitative nature of this study and the small non-randomly selected sample, some interesting and meaningful trends and patterns were found which gave insights into aspects of energy-efficient new housing construction and builders within the Greater Lansing area.

The decision to use energy-efficient features in new houses was triggered by interest or awareness, along with cost and consumer demand (marketing) Tables 4.10, 4.11, 4.12 and 4.15. In this study, builders have tended not to utilize solar energy; however, the builders have utilized conventional features above and beyond the requirements of the Michigan Energy Code within the Greater Lansing area.

Group A utilized more energy-efficient features in their most recent homes, tended to be more actively involved in determining the heating system requirements, tended to think of themselves more as leaders than followers, and were more willing to try new products than Group B. This suggests the builders which were more innovative and involved in the planning and construction process were the builders which were most likely to build energy-efficient houses and use more energy-efficient features. The builders in Group A

tended to use more energy-efficient features and also built smaller one-story ranch homes that were less expensive than those houses built by Group B. Group B built fewer but larger two-story homes which were more expensive and utilized fewer energy features. The results suggest that the builders in each group were involved in different markets and their attitudes are geared to maintain sales and marketing within their own marketing area.

Marketing and cost considerations were determined as the key factors in decision making in whether to include or not include energy-efficient features in new construction. The costs alone were found as the key reason for consumer resistance to energy-efficient features. The builders which indicated that cost was the most important consumer resistant factor responded that consumers were leery of the amount of savings energy features would generate; or that the buyers were unwilling or unable to pay for features even if they would save them money in the long run, or that buyers questioned payback time.

Concerning the risk factors in using energy-efficient features, a difference was observed between the two groups of home builders. Group A stated problems in getting energy-efficient features properly installed as their most important risk, while Group B stated difficulty in selling the house. Group A built smaller, less expensive one-story homes, compared with Group B's larger two-story more expensive homes. Group A also tended to use more energy features per house than Group B. The data which are evidenced here suggest that a smaller house has a higher proportion of energy features per total cost of the house and that new smaller homes are more likely to incorporate energy-efficient features. Unfortunately, the energy-efficient features added more proportionately to the cost of a lower priced home, where initial cost is much more critical in the customer/builder decision. Group B's larger two-story houses tended to be more expensive and had fewer energy-conservation features per house than Group A's. Evidence suggests that the higher priced house tends to have fewer energy features installed.

All the builders realized cutting infiltration was the major factor in reducing heat loss, yet this did not lead the builders in Group B to install more features. Group B felt their houses were tight enough and did not require the additional features (such as taping seams on styrofoam sheathing). Whereas Group A tended to strive for as tight a house shell as possible, including items like taping the seams of the styrofoam wall sheathing and placing foam insulation around windows and doors, instead of simply stuffing insulation around them.

Concerning the obstacles the builders have in constructing energy-efficient houses, the builders of both groups again identified cost or marketing as their largest obsta cle. For example, costs related to initial costs and expenses in operating and, marketing related to a product the consumer demands.

It was found builders would not cut insulation to save building construction costs and further that Group A's energy features would add $38.67 per month compared to Group B's $34.66 per month to the average monthly mortgage payment.

The decisions on whether to include or not include specific energy conservation features were found to depend on the decision criteria a builder uses and how they assess energy conservation features in terms of their criteria on cost, marketing, ease of installation and product performance.

The builder that is innovative, aggressive, constantly monitoring consumer trends and getting involved in planning and construction process will build the more energy-efficient house of tomorrow.

5.2 Conclusions

On the whole, Group A and Group B did not differ substantially overall; however, results from this study shows Group A tended to be more involved in decisions specifying type and capacity of heating/cooling systems, be more concerned about energy, work more closely with subcontractors, build smaller, less costly and more energy-efficient houses with more energy features than Group B.

Along with the characteristics mentioned above, Group A's attitude toward energy conservation tended to inhibit the adoption of new ideas for saving money and energy in housing. However, Group B, which was thought not to be as energy conscious, was found to be including more features than anticipated. The study also points out the following conclusions:

1. Builders are responding to consumer demands and interests in energy-efficient features which in turn are increasing the number of energy-efficient features used in new houses.

2. Policies and programs designed to promote the use of insulation and energy-efficient HVAC systems are working; however, the calculations involved in determining heat loss/gain needs more emphasis to aid the home builder in decision making.

3. Home builders look to energy conservation features not as an innovation, but as a way to maintain sales in their own markets.

4. When home builders can adequately justify costs in relation to economic payback, the consumer does not resist more energy-efficient features and tends not to concentrate on initial costs.

5. Cost and marketing are key factors for decision making.

6. Builders did not cut insulation to save costs.

5.3 Limitations

1. A major limitation of this study was the sample size and the non-random selection of the sample. While the sample may be representative of the builders within the Greater Lansing area, it is not possible to statistically examine the sample; however, in a preliminary study of this kind, the objective is to discover general and relevant insights which could be tested with more statistical rigor in the future.

2. The study was a qualitative analysis approach with open-ended interviews, where a chance of interviewer biases could color the results, an attempt to overcome known biases was done by using the open-ended question systematically in each interview.

3. The researcher was limited to the information received during the open-ended interviews and did not check the home builders figures or files for verification.

5.4 Implications

5.4.1 Education

The builders in this study were educated and had the experience. Yet, even with this knowledge, greater emphasis must be placed on expanding the education efforts in the area of heat loss/gain calculations, determining economic investment, and cost effectiveness for energy-efficient housing. Results of this study suggest, educational efforts should be focused on those areas of the housing industry which could benefit most from information about energy savings i.e., subcontractors and consumers to whom the builders respond.

5.4.2 Governmental Policy

Federal, state and local governmental policy has had a major effect on saving energy for new residential housing. All the builders in this study knew the Michigan Energy Code was required by law as a minimum standard. The standard needs to be updated to increase the minimum requirements of energy features, as all the builders were approximately doubling the standard in their most recent houses.

5.4.3 Incentive Policy

Policy on energy needs to be financially more attractive; increasing tax rebates, having low-interest loans on energy-efficient houses for new construction or 100% financing on energy-conservation features.

This study found cost as one of the key factors for decision making. If the costs of energy-conservation features were not added to the equity investment, and if builders could show the consumer that the savings in operating costs were greater than the principal and interest payments required to finance the installation of energy features, a positive contribution to home sales would be possible. This, however, would require a whole new program at the state level where interest rates for second mortgages could be equal to the rate at which the state borrows money plus an administration charge.

A way of creating a different program would be to take into consideration home operating costs in the loan-to-value ratio. This program would show that if investments in energy-conservation features reduced operating costs more than increased interest payments, the lower the down payment. This may also have a positive impact to increase sales and qualify more home buyers.

5.4.4. Provide Information Programs

Marketing was found in this study as one of the factors in decision making. Providing better information about energy-conservation features is one way of reducing the risk and possibly increasing the builders' adoption of energy features. This could be accomplished by establishing a market research service where builders could find out what consumers are interested in for energy conservation and how much they are willing to pay. Also, the service could determine cost effectiveness of energy features, product reliability and maintain a small library concerning energy and home building.

5.4.5 Continue Research and Demonstrations

Aggressive and energy-conscious builders may adopt an energy feature by reading about it. However, many others need to see the feature in place and/or in use. Research and demonstrations should be stressed further to include cost, ease of installation, dependability and consumer acceptance.

Finally, it can be implied from this study that home builders are constructing more energy-efficient housing today than perhaps was thought to be the case before the study was completed. It was clear that marketing and cost considerations were the primary factors which the home builder considered in using an energy-efficient feature and that several other factors (such as attitudes toward conservation, technical knowledge, governmental regulations, desire to improve thermal performance, and support of subcontractors) played a significant supporting role.

5.5 Future Research Suggestions

Along with the implications to the study, there are several areas which the researcher feels require further research.

Further research work in the use of energy-efficient designs and features could include the following:

1. Improve the area of cost effectiveness

   a. Details of the cost implications concerning the added expense in using an energy-efficient feature compared to the amount of energy saved.

2. Perform a similar study on a randomly selected sample perhaps attempting to study a national sample of home builders and use statistical analysis in the evaluation of the results.

3. Work in the area of determining the optimum economic investment for any given house taking into consideration local climate, choice of energy source, style of house and energy features utilized as well as behaviors of the households.

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1981 Annual Report to Congress, 1982, Energy Statistics, Volume 2 of 3, DOE/EIA - 0173(81)12, May, 1982 (mimeographed tables and figures)

APPENDICES

APPENDIX A

Consumption of Energy by Type, 1951-1981

Year	Coal[1]		Natural Gas		Petroleum[2]		Hydropower[3]		Nuclear Power		Geothermal[4]		Wood and Waste[5]		Net Imports of Coal Coke		Total Energy Consumption	Change from Previous Year
	Quadrillion Btu	Million Short Tons	Quadrillion Btu	Trillion Cubic Feet	Quadrillion Btu	Million Barrels	Quadrillion Btu	Billion kWh[6]	Quadrillion Btu	Billion kWh[6]	Quadrillion Btu	Billion kWh[6]	Quadrillion Btu	Billion kWh[6]	Quadrillion Btu	Thousand Short Tons	Quadrillion Btu	Percent[7]
1951	13.20	505.9	7.05	6.81	14.43	2,561	1.45	106.6	0	0	0	0	0	0	-0.02	-895	36.11	7.4
1952	11.84	454.1	7.55	7.29	14.96	2,661	1.50	112.0	0	0	0	0	0	0	-0.01	-479	35.83	-0.8
1953	11.87	454.8	7.91	7.64	15.56	2,774	1.44	111.6	0	0	0	0	0	0	-0.01	-363	36.76	2.6
1954	10.17	389.9	8.33	8.06	15.84	2,831	1.39	114.0	0	0	0	0	0	0	-0.01	-272	35.73	-2.8
1955	11.52	447.0	9.00	8.69	17.25	3,086	1.41	120.3	0	0	0	0	0	0	-0.01	-406	39.17	9.6
1956	11.72	456.9	9.61	9.29	17.94	3,212	1.49	129.8	0	0	0	0	0	0	-0.01	-525	40.75	4.0
1957	11.14	434.5	10.19	9.85	17.93	3,215	1.56	137.0	0	0	0	0	0	0	-0.02	-704	40.80	0.1
1958	9.83	385.7	10.66	10.30	18.53	3,328	1.63	146.9	(8)	0.2	0	0	0	0	-0.01	-271	40.65	-0.4
1959	9.79	385.1	11.72	11.32	19.32	3,477	1.59	144.7	(8)	0.2	0	0	0	0	-0.01	-337	42.41	4.3
1960	10.12	398.0	12.39	11.97	19.92	3,586	1.65	153.7	0.01	0.5	(8)	0	(8)	0.1	-0.01	-227	44.08	3.9
1961	9.89	390.3	12.93	12.49	20.22	3,641	1.68	157.5	0.02	1.7	(8)	0.1	(8)	0.1	-0.01	-318	44.72	1.5
1962	10.17	402.2	13.73	13.27	21.05	3,796	1.82	172.2	0.03	2.3	(8)	0.1	(8)	0.1	-0.01	-222	46.80	4.6
1963	10.69	423.5	14.40	13.97	21.70	3,921	1.77	169.1	0.04	3.2	(8)	0.2	(8)	0.1	-0.01	-298	48.61	3.9
1964	11.25	445.7	15.29	14.81	22.30	4,034	1.91	182.3	0.04	3.3	(8)	0.2	(8)	0.1	-0.01	-421	50.78	4.5
1965	11.89	472.0	15.77	15.28	23.25	4,202	2.06	196.8	0.04	3.7	(8)	0.2	(8)	0.3	-0.02	-744	52.99	4.4
1966	12.48	497.7	17.00	16.45	24.40	4,411	2.07	199.0	0.06	5.5	(8)	0.2	(8)	0.3	-0.03	-1,006	55.99	5.7
1967	12.24	491.4	17.94	17.39	25.28	4,585	2.34	224.6	0.09	7.7	0.01	0.3	(8)	0.3	-0.02	-618	57.89	3.4
1968	12.66	509.8	19.21	18.63	26.98	4,902	2.34	225.2	0.14	12.5	0.01	0.4	(8)	0.4	-0.02	-898	61.32	5.9
1969	12.72	516.4	20.68	20.06	28.34	5,160	2.66	254.5	0.15	13.9	0.01	0.6	(8)	0.3	-0.04	-1,456	64.53	5.2
1970	12.68	523.2	21.79	21.14	29.52	5,364	2.65	252.9	0.24	21.8	0.01	0.5	(8)	0.4	-0.06	-2,325	66.83	3.6
1971	12.01	501.6	22.47	21.79	30.56	5,553	2.86	273.1	0.41	38.1	0.01	0.5	(8)	0.3	-0.03	-1,335	68.30	2.2
1972	12.45	524.3	22.70	22.10	32.96	5,990	2.94	283.6	0.58	54.1	0.03	1.5	(8)	0.3	-0.03	-1,047	71.63	4.9
1973	13.30	562.6	22.51	22.05	34.84	6,317	3.01	289.7	0.91	83.5	0.04	2.0	(8)	0.3	-0.01	-317	74.61	4.2
1974	12.88	558.4	21.73	21.22	33.45	6,078	3.31	316.9	1.27	114.0	0.05	2.5	(8)	0.3	0.06	2,262	72.76	-2.5
1975	12.82	562.6	19.95	19.54	32.73	5,958	3.22	309.3	1.90	172.5	0.07	3.2	(8)	0.2	0.01	546	70.71	-2.8
1976	13.73	603.8	20.35	19.95	35.17	6,391	3.07	296.5	2.11	191.1	0.08	3.6	(8)	0.3	(8)	-4	74.51	5.4
1977	13.96	625.3	19.93	19.52	37.12	6,727	2.51	241.0	2.70	250.9	0.08	3.6	0.01	0.5	0.02	586	76.33	2.4
1978	13.85	625.2	20.00	19.63	37.97	6,879	3.14	303.2	3.02	276.4	0.06	3.0	(8)	0.3	0.13	5,029	78.18	2.4
1979	15.11	680.5	20.67	20.24	37.12	6,757	3.14	303.4	2.71	255.2	0.08	3.9	0.01	0.5	0.07	2,534	78.91	0.9
1980	15.46	702.7	20.39	19.88	34.20	6,242	3.11	300.1	2.67	251.1	0.11	5.1	(8)	0.4	-0.04	-1,412	75.91	-3.8
1981[9]	16.01	727.7	19.93	19.42	32.00	5,840	2.97	287.0	2.90	272.3	0.12	5.7	(8)	0.4	-0.02	-643	73.91	-2.6

[1] Bituminous coal, lignite, and anthracite.
[2] Refined petroleum products supplied including natural gas plant liquids and crude oil burned as fuel.
[3] Electric utility and industrial generation of hydropower and net electricity imports.
[4] Consumed by electric utilities.
[5] Wood, refuse, and other vegetal fuels consumed by electric utilities. Converted to Btu by applying national average heat rates for fossil fuel steam electric plants. Data do not include the consumption of wood derived fuel (other than that consumed by the electric utility industry) which amounted to an estimated 2.2 quadrillion Btu 1981. This table excludes small quantities of energy forms for which consistent historical data are not available, such as solar energy obtained by the use of thermal and photovoltaic collectors; wind energy; and geothermal, biomass, and waste energy other than that consumed at electric utilities.
[6] See Explanatory Note 6.
[7] Percent change calculated from data prior to rounding.
[8] Less than 0.005 quadrillion Btu.
[9] Preliminary.
Note: Sum of components may not equal total due to independent rounding.

APPENDIX B

Consumption of Energy by End-Use Sector,[1] 1951-1981

(Quadrillion Btu)

Year	Residential and Commercial: Without Electricity Distributed	Residential and Commercial: With Electricity Distributed[2]	Industrial: Without Electricity Distributed	Industrial: With Electricity Distributed[2]	Transportation: Without Electricity Distributed	Transportation: With Electricity Distributed[2]	Electric Utilities	Total Energy Consumption
1951	7.00	9.60	14.66	17.41	8.99	9.11	5.45	36.11
1952	7.04	9.80	14.18	16.99	8.94	9.04	5.67	35.83
1953	6.83	9.75	14.83	17.86	9.05	9.15	6.06	36.76
1954	7.02	10.04	13.76	16.77	8.83	8.91	6.12	35.73
1955	7.47	10.62	15.44	18.99	9.47	9.55	6.79	39.17
1956	7.78	11.19	15.88	19.70	9.79	9.86	7.30	40.75
1957	7.54	11.17	15.61	19.46	9.84	9.90	7.55	40.80
1958	8.04	11.83	15.16	18.82	9.97	10.02	7.51	40.65
1959	8.23	12.33	15.80	19.74	10.30	10.35	8.08	42.41
1960	8.91	13.22	16.46	20.34	10.48	10.52	8.23	44.08
1961	9.13	13.63	16.47	20.44	10.62	10.66	8.51	44.72
1962	9.60	14.43	17.04	21.23	11.10	11.14	9.06	46.80
1963	9.62	14.86	17.79	22.17	11.54	11.58	9.66	48.61
1964	9.72	15.35	18.82	23.50	11.89	11.92	10.34	50.78
1965	10.13	16.19	19.50	24.47	12.30	12.33	11.07	52.99
1966	10.53	17.13	20.39	25.78	13.04	13.08	12.03	55.99
1967	11.09	18.17	20.38	26.00	13.69	13.72	12.73	57.89
1968	11.44	19.30	21.16	27.20	14.80	14.83	13.92	61.32
1969	11.94	20.66	21.91	28.40	15.43	15.46	15.25	64.53
1970	12.18	21.76	22.32	29.00	16.03	16.06	16.29	66.83
1971	12.38	22.67	22.05	28.96	16.65	16.68	17.22	68.30
1972	12.64	23.73	22.77	30.24	17.63	17.66	18.58	71.63
1973	12.24	24.20	23.86	31.88	18.49	18.52	20.01	74.61
1974	11.74	23.77	22.85	30.94	18.00	18.03	20.16	72.76
1975	11.58	23.92	20.57	28.60	18.14	18.18	20.42	70.71
1976	12.25	25.01	21.68	30.44	19.03	19.07	21.55	74.51
1977	11.83	25.41	21.97	31.18	19.70	19.74	22.82	76.33
1978	11.93	26.00	22.12	31.56	20.58	20.61	23.55	78.18
1979	11.79	26.08	22.58	32.39	20.40	20.43	24.14	78.91
1980	10.98	25.87	20.85	30.36	19.65	19.68	24.44	75.91
1981[3]	10.69	25.64	19.39	29.02	19.18	19.22	24.63	73.91

[1] Data do not include consumption of wood derived fuel (other than that consumed by the electric utility industry) which amounted to an estimated 2.2 quadrillion Btu in 1981. Also, small quantities of other energy forms for which consistent historical data are not available, such as solar energy obtained by the use of thermal and photovoltaic collectors; wind energy; and geothermal, biomass, and waste energy other than that consumed at electric utilities, are not included. See Explanatory Note 2.

[2] Energy consumption by electric utilities is allocated to the three major end-use sectors in proportion to electricity sales.

[3] Preliminary.

Note: Sum of components may not equal total due to independent rounding.

APPENDIX C

Prices of Domestically Produced Fossil Fuels, 1951-1981

(Cents per Million Btu)

Year	Crude Oil [1]		Natural Gas [2]		Bituminous Coal and Lignite		Anthracite		Composite [3]	
	Current	Constant [4]	Current	Constant [4]	Current	Constant [4]	Current	Constant [4]	Current	Constant [4]
1951	43.6	76.4	6.6	11.6	18.8	32.9	40.2	70.4	25.5	44.7
1952	43.6	75.3	7.0	12.1	18.7	32.3	38.9	67.2	25.7	44.4
1953	46.2	78.5	8.2	13.9	18.8	32.0	40.2	68.3	26.9	45.7
1954	47.9	80.4	9.1	15.3	17.3	29.1	35.6	59.8	27.4	46.0
1955	47.8	78.6	9.3	15.3	17.3	28.4	32.6	53.6	27.0	44.4
1956	48.1	76.6	9.7	15.4	18.6	29.6	34.2	54.5	27.5	43.8
1957	53.3	82.1	10.2	15.7	19.6	30.2	37.6	57.9	29.7	45.7
1958	51.9	78.6	10.7	16.2	18.7	28.3	37.3	56.5	28.9	43.8
1959	50.0	74.0	11.6	17.2	18.6	27.5	35.1	51.9	28.3	41.9
1960	49.7	72.8	12.6	18.3	18.3	26.6	33.0	48.0	28.1	40.9
1961	49.8	71.8	13.6	19.6	17.9	25.8	33.8	48.8	28.5	41.1
1962	50.0	70.8	14.0	19.8	17.5	24.8	32.8	46.5	28.4	40.2
1963	49.8	69.5	14.3	20.0	17.2	24.0	35.7	49.8	28.0	39.1
1964	49.7	68.3	14.0	19.2	17.5	24.0	37.0	50.8	27.7	38.1
1965	49.3	66.3	14.2	19.1	17.5	23.5	35.3	47.5	27.5	37.0
1966	49.7	64.7	14.2	18.5	17.9	23.3	33.7	43.9	27.7	36.1
1967	50.3	63.6	14.5	18.3	18.4	23.3	34.7	43.9	28.3	35.8
1968	50.7	61.4	14.7	17.8	18.6	22.5	37.6	45.6	28.5	34.5
1969	53.3	61.4	15.1	17.4	20.0	23.0	42.3	48.7	29.6	34.1
1970	54.8	59.9	15.5	16.9	25.5	27.9	47.1	51.5	31.6	34.6
1971	58.4	60.8	16.5	17.2	29.2	30.4	51.4	53.5	33.9	35.3
1972	58.4	58.4	16.9	16.9	31.9	31.9	52.9	52.9	34.6	34.6
1973	67.1	63.5	19.8	18.7	35.5	33.6	58.9	55.7	39.4	37.3
1974	118.4	103.0	27.7	24.1	66.4	57.8	98.4	85.6	67.3	58.6
1975	132.2	105.3	40.6	32.3	82.9	66.0	137.9	109.8	82.0	65.3
1976	141.2	106.9	53.1	40.2	83.9	63.5	149.0	112.8	89.8	68.0
1977	147.8	105.7	72.3	51.7	87.3	62.4	150.4	107.6	100.6	71.9
1978	155.2	103.4	83.2	55.4	97.1	64.7	149.9	99.9	111.1	74.0
1979	217.9	133.9	107.9	66.3	104.7	64.3	174.1	107.0	141.3	86.8
1980	365.3	206.0	145.9	82.3	106.1	59.8	188.4	106.2	200.2	112.9
1981[5]	535.0	277.6	187.7	97.4	112.3	58.3	203.4	105.6	270.4	140.3

[1] Includes lease condensate.
[2] Wet natural gas, prior to extraction of natural gas plant liquids.
[3] Derived by multiplying the price per Btu of each fossil fuel by the total Btu content of the production of each fossil fuel and dividing the accumulated price of total fossil fuel production by the accumulated Btu content of total fossil fuel production.
[4] Constant 1972 prices calculated using GNP implicit price deflators, 1972 = 100. See Units of Measure, Conversion Factors, Price Deflators, and Energy Equivalents section.
[5] Estimated.
Note: All fuel prices taken as close as possible to the point of production.

APPENDIX D

Trade in Energy, 1951-1981
(Quadrillion Btu)

Year	Imports					Exports					Net Trade [1]				
	Coal [2]	Petroleum [3]	Natural Gas (Dry)	Other [4]	Total	Coal [2]	Petroleum [3]	Natural Gas (Dry)	Other [4]	Total	Coal [2]	Petroleum [3]	Natural Gas (Dry)	Other [4]	Total
1951	0.01	1.87	([5])	0.04	1.92	1.68	0.89	0.03	0.03	2.62	1.67	-0.98	0.03	-0.01	0.71
1952	0.01	2.11	0.01	0.04	2.17	1.40	0.91	0.03	0.02	2.37	1.40	-1.20	0.02	-0.02	0.20
1953	0.01	2.28	0.01	0.04	2.34	0.98	0.84	0.03	0.02	1.87	0.97	-1.44	0.02	-0.02	-0.47
1954	0.01	2.32	0.01	0.04	2.37	0.91	0.75	0.03	0.01	1.70	0.91	-1.58	0.02	-0.02	-0.67
1955	0.01	2.75	0.01	0.06	2.83	1.46	0.77	0.03	0.02	2.29	1.46	-1.98	0.02	-0.04	-0.54
1956	0.01	3.17	0.01	0.06	3.25	1.98	0.91	0.04	0.02	2.95	1.98	-2.26	0.03	-0.04	-0.30
1957	0.01	3.46	0.04	0.06	3.57	2.17	1.20	0.04	0.04	3.45	2.16	-2.26	([5])	-0.02	-0.12
1958	0.01	3.72	0.14	0.05	3.92	1.42	0.58	0.04	0.02	2.06	1.41	-3.14	-0.10	-0.03	-1.86
1959	0.01	3.91	0.14	0.06	4.11	1.05	0.45	0.02	0.02	1.54	1.04	-3.46	-0.12	-0.03	-2.57
1960	0.01	4.00	0.16	0.06	4.23	1.02	0.48	0.01	0.02	1.48	1.02	-3.57	-0.15	-0.04	-2.74
1961	([5])	4.19	0.23	0.04	4.46	0.98	0.37	0.01	0.02	1.38	0.98	-3.82	-0.22	-0.02	-3.08
1962	0.01	4.56	0.42	0.03	5.01	1.08	0.36	0.02	0.03	1.48	1.08	-4.20	-0.40	([5])	-3.53
1963	0.01	4.65	0.42	0.03	5.10	1.36	0.44	0.02	0.03	1.85	1.35	-4.21	-0.40	0.01	-3.25
1964	0.01	4.96	0.46	0.07	5.49	1.34	0.43	0.02	0.06	1.85	1.33	-4.53	-0.44	-0.01	-3.65
1965	0.00	5.40	0.47	0.04	5.92	1.38	0.39	0.03	0.06	1.86	1.37	-5.01	-0.44	0.02	-4.06
1966	([5])	5.63	0.50	0.05	6.18	1.35	0.41	0.03	0.06	1.85	1.35	-5.21	-0.47	0.01	-4.32
1967	0.01	5.56	0.58	0.04	6.19	1.35	0.65	0.08	0.06	2.15	1.35	-4.91	-0.50	0.02	-4.04
1968	0.01	6.21	0.67	0.04	6.93	1.38	0.49	0.10	0.07	2.03	1.37	-5.73	-0.58	0.02	-4.90
1969	([5])	6.90	0.75	0.06	7.71	1.53	0.49	0.05	0.08	2.15	1.53	-6.42	-0.70	0.03	-5.56
1970	([5])	7.47	0.85	0.07	8.39	1.94	0.55	0.07	0.11	2.66	1.93	-6.92	-0.77	0.04	-5.72
1971	([5])	8.54	0.96	0.08	9.58	1.55	0.47	0.08	0.08	2.18	1.54	-8.07	-0.88	-([5])	-7.41
1972	([5])	10.30	1.05	0.11	11.46	1.53	0.47	0.08	0.06	2.14	1.53	-9.83	-0.97	-0.06	-9.32
1973	([5])	13.47	1.06	0.20	14.73	1.45	0.49	0.08	0.06	2.07	1.44	-12.98	-0.98	-0.14	-12.66
1974	0.06	13.13	0.99	0.25	14.42	1.64	0.46	0.08	0.06	2.24	1.58	-12.66	-0.91	-0.19	-12.18
1975	0.02	12.95	0.98	0.16	14.11	1.79	0.44	0.07	0.09	2.39	1.77	-12.51	-0.90	-0.08	-11.73
1976	0.03	15.67	0.99	0.15	16.84	1.62	0.47	0.07	0.06	2.21	1.59	-15.20	-0.92	-0.09	-14.63
1977	0.04	18.76	1.04	0.26	20.09	1.47	0.51	0.06	0.06	2.10	1.42	-18.24	-0.98	-0.20	-18.00
1978	0.07	17.82	0.99	0.37	19.26	1.10	0.77	0.05	0.03	1.95	1.02	-17.06	-0.94	-0.34	-17.31
1979	0.05	17.93	1.30	0.34	19.62	1.78	1.00	0.06	0.06	2.90	1.73	-16.93	-1.24	-0.28	-16.72
1980	0.03	14.66	1.01	0.28	15.97	2.40	1.16	0.05	0.10	3.71	2.37	-13.50	-0.96	-0.18	-12.27
1981[6]	0.03	12.65	0.90	0.30	13.87	2.94	1.26	0.05	0.08	4.34	2.92	-11.39	-0.85	-0.22	-9.54

[1] Net trade = exports minus imports.
[2] Bituminous coal, lignite, and anthracite.
[3] Crude oil and refined petroleum products, including unfinished oils and natural gas plant liquids. Includes imports into the Strategic Petroleum Reserve which began in 1977.
[4] Coal coke and small amounts of electricity transmitted across U.S. borders with Canada and Mexico.
[5] Less than 0.005 quadrillion Btu.
[6] Preliminary.
Note: Sum of components may not equal totals or net trade items due to independent rounding.
Note: Includes trade between the United States (50 states and the District of Columbia) and its territories and possessions.

APPENDIX E

Surface Conductances and Resistances for Air

All conductance values expressed in Btu/(hr · ft² · F).

Position of Surface	Direction of Heat Flow	Non-reflective ε = 0.90 h_i	R	Reflective ε = 0.20 h_i	R	Reflective ε = 0.05 h_i	R
SECTION A. Surface Conductances and Resistances							
STILL AIR							
Horizontal	Upward	1.63	*0.61*	0.91	*1.10*	0.76	*1.32*
Sloping—45 deg	Upward	1.60	*0.62*	0.88	*1.14*	0.73	*1.37*
Vertical	Horizontal	1.46	*0.68*	0.74	*1.35*	0.59	*1.70*
Sloping—45 deg	Downward	1.32	*0.76*	0.60	*1.67*	0.45	*2.22*
Horizontal	Downward	1.08	*0.92*	0.37	*2.70*	0.22	*4.55*
MOVING AIR (Any Position)		h_o	R	h_o	R	h_o	R
15-mph Wind (for winter)	Any	6.00	0.17				
7.5-mph Wind (for summer)	Any	4.00	0.25				

Coefficients of Transmission (*U*) for Slab Doors

Btu per (hr · ft² · F)

Thickness[a]	Winter: Solid Wood, No Storm Door	Winter: Storm Door[b] Wood	Winter: Storm Door[b] Metal	Summer: No Storm Door
1-in.	0.64	0.30	0.39	0.61
1.25-in.	0.55	0.28	0.34	0.53
1.5-in.	0.49	0.27	0.33	0.47
2-in.	0.43	0.24	0.29	0.42
Steel Door[14]				
1.75 in.				
A[c]	0.59	—	—	0.58
B[d]	0.19	—	—	0.18
C[e]	0.47	—	—	0.46

[a]Nominal thickness.
[b]Values for wood storm doors are for approximately 50% glass; for metal storm door values apply for any percent of glass.
[c]A = Mineral fiber core (2 lb/ft³).
[d]B = Solid urethane foam core with thermal break.
[e]C = Solid polystyrene core with thermal break.

Thermal Properties of Typical Building and Insulating Materials—(Design Values)[a]

(For Industrial Insulation Design Values, see Table 3B). These constants are expressed in Btu per (hour) (square foot) (degree Fahrenheit temperature difference). Conductivities *(k)* are per inch thickness, and conductances *(C)* are for thickness or construction stated, not per inch thickness. **All values are for a mean temperature of 75 F, except as noted by an asterisk (*) which have been reported at**

Description	Density (lb/ft³)	Conductivity (*k*)	Conductance (*C*)	Resistance[b] (*R*): Per inch thickness (1/*k*)	Resistance[b] (*R*): For thickness listed (1/*C*)	Specific Heat, Btu/(lb) (deg F)
BUILDING BOARD						
Boards, Panels, Subflooring, Sheathing Woodboard Panel Products						
Asbestos-cement board	120	4.0	—	*0.25*	—	0.24
Asbestos-cement board .... 0.125 in.	120	—	33.00	—	*0.03*	
Asbestos-cement board .... 0.25 in.	120	—	16.50	—	*0.06*	
Gypsum or plaster board .... 0.375 in.	50	—	3.10	—	*0.32*	0.26
Gypsum or plaster board .... 0.5 in.	50	—	2.22	—	*0.45*	
Gypsum or plaster board .... 0.625 in.	50	—	1.78	—	*0.56*	
Plywood (Douglas Fir)	34	0.80	—	*1.25*	—	0.29
Plywood (Douglas Fir) .... 0.25 in.	34	—	3.20	—	*0.31*	
Plywood (Douglas Fir) .... 0.375 in.	34	—	2.13	—	*0.47*	
Plywood (Douglas Fir) .... 0.5 in.	34	—	1.60	—	*0.62*	
Plywood (Douglas Fir) .... 0.625 in.	34	—	1.29	—	*0.77*	

Thermal Properties of Typical Building and Insulating Materials—(Design Values)[a]

Description	Customary Unit					
	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[b] (R) Per inch thickness (1/k)	Resistance[b] (R) For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Plywood or wood panels . . . 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable Fiber Board						
Sheathing, regular density . . . 0.5 in.	18	—	0.76	—	1.32	0.31
. . . 0.78125 in.	18	—	0.49	—	2.06	
Sheathing intermediate density . . . 0.5 in.	22	—	0.82	—	1.22	0.31
Nail-base sheathing . . . 0.5 in.	25	—	0.88	—	1.14	0.31
Shingle backer . . . 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer . . . 0.3125 in.	18	—	1.28	—	0.78	
Sound deadening board . . . 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels, plain or acoustic . . .	18	0.40	—	2.50	—	0.14
. . . 0.5 in.	18	—	0.80	—	1.25	
. . . 0.75 in.	18	—	0.53	—	1.89	
Laminated paperboard . . .	30	0.50	—	2.00	—	0.33
Homogeneous board from repulped paper . . .	30	0.50	—	2.00	—	0.28
Hardboard						
Medium density . . .	50	0.73	—	1.37	—	0.31
High density, service temp. service underlay . . .	55	0.82	—	1.22	—	0.32
High density, std. tempered . . .	63	1.00	—	1.00	—	0.32
Particleboard						
Low density . . .	37	0.54	—	1.85	—	0.31
Medium density . . .	50	0.94	—	1.06	—	0.31
High density . . .	62.5	1.18	—	0.85	—	0.31
Underlayment . . . 0.625 in.	40	—	1.22	—	0.82	0.29
Wood subfloor . . . 0.75 in.		—	1.06	—	0.94	0.33
BUILDING MEMBRANE						
Vapor—permeable felt . . .	—	—	16.70	—	0.06	
Vapor—seal, 2 layers of mopped 15-lb felt . . .	—	—	8.35	—	0.12	
Vapor—seal, plastic film . . .	—	—	—	—	Negl.	
FINISH FLOORING MATERIALS						
Carpet and fibrous pad . . .	—	—	0.48	—	2.08	0.34
Carpet and rubber pad . . .	—	—	0.81	—	1.23	0.33
Cork tile . . . 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo . . . 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber . . .	—	—	20.00	—	0.05	0.30
vinyl asbestos . . .						0.24
ceramic . . .						0.19
Wood, hardwood finish . . . 0.75 in.			1.47		0.68	
INSULATING MATERIALS						
BLANKET AND BATT						
Mineral Fiber, fibrous form processed from rock, slag, or glass						
approx.[c] 2-2.75 in. . . .	0.3-2.0	—	0.143	—	7[d]	0.17-0.23
approx.[c] 3-3.5 in. . . .	0.3-2.0	—	0.091	—	11[d]	
approx.[c] 3.50-6.5 . . .	0.3-2.0	—	0.053	—	19[d]	
approx.[c] 6-7 in. . . .	0.3-2.0		0.045		22[d]	
approx.[d] 8.5 in. . . .	0.3-2.0		0.033		30[d]	
BOARD AND SLABS						
Cellular glass . . .	8.5	0.38	—	2.63	—	0.24
Glass fiber, organic bonded . . .	4-9	0.25	—	4.00	—	0.23
Expanded rubber (rigid) . . .	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene extruded Cut cell surface . . .	1.8	0.25	—	4.00	—	0.29
Expanded polystyrene extruded Smooth skin surface . . .	2.2	0.20	—	5.00	—	0.29
Expanded polystyrene extruded Smooth skin surface . . .	3.5	0.19	—	5.26	—	
Expanded polystyrene, molded beads . . .	1.0	0.28	—	3.57	—	0.29
Expanded polyurethane[f] (R-11 exp.) . . .	1.5	0.16	—	6.25	—	0.38
(Thickness 1 in. or greater) . . .	2.5					

Thermal Properties of Typical Building and Insulating Materials—(Design Values)[a]

Description	Customary Unit					
	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[b] (R) Per inch thickness (1/k)	Resistance[b] (R) For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Mineral fiber with resin binder	15	0.29	—	*3.45*	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	*2.94*	—	
Acoustical tile	18	0.35	—	*2.86*	—	0.19
Acoustical tile	21	0.37	—	*2.70*	—	
Mineral fiberboard, wet molded						
Acoustical tile[g]	23	0.42	—	*2.38*	—	0.14
Wood or cane fiberboard						
Acoustical tile[g] 0.5 in.	—	—	0.80	—	*1.25*	0.31
Acoustical tile[g] 0.75 in.	—	—	0.53	—	*1.89*	
Interior finish (plank, tile)	15	0.35	—	*2.86*	—	0.32
Wood shredded (cemented in preformed slabs)	22	0.60	—	*1.67*	—	0.31
LOOSE FILL						
Cellulosic insulation (milled paper or wood pulp)	2.3-3.2	0.27-0.32	—	*3.13-3.70*	—	0.33
Sawdust or shavings	8.0-15.0	0.45	—	*2.22*	—	0.33
Wood fiber, softwoods	2.0-3.5	0.30	—	*3.33*	—	0.33
Perlite, expanded	5.0-8.0	0.37	—	*2.70*	—	0.26
Mineral fiber (rock, slag or glass)						
approx.[e] 3.75-5 in.	0.6-2.0	—	—		11	0.17
approx.[e] 6.5-8.75 in.	0.6-2.0	—	—		19	
approx.[e] 7.5-10 in.	0.6-2.0	—	—		22	
approx.[e] 10.25-13.75 in.	0.6-2.0	—	—		30	
Vermiculite, exfoliated	7.0-8.2	0.47	—	*2.13*	—	3.20
	4.0-6.0	0.44	—	*2.27*	—	
ROOF INSULATION[h]						
Preformed, for use above deck						
Different roof insulations are available in different thicknesses to provide the design C values listed.[h] Consult individual manufacturers for actual *thickness of their material.*			0.72 to 0.12		*1.39 to 8.33*	
MASONRY MATERIALS						
CONCRETES						
Cement mortar	116	5.0	—	*0.20*	—	
Gypsum-fiber concrete 87.5% gypsum, 12.5% wood chips	51	1.66	—	*0.60*	—	0.21
Lightweight aggregates including expanded shale, clay or slate; expanded slags; cinders; pumice; vermiculite; also cellular concretes	120	5.2	—	*0.19*	—	
	100	3.6	—	*0.28*	—	
	80	2.5	—	*0.40*	—	
	60	1.7	—	*0.59*	—	
	40	1.15	—	*0.86*	—	
	30	0.90	—	*1.11*	—	
	20	0.70		*1.43*		
Perlite, expanded	40	0.93		*1.08*		
	30	0.71		*1.41*		
	20	0.50		*2.00*		0.32
Sand and gravel or stone aggregate (oven dried)	140	9.0	—	*0.11*		0.22
Sand and gravel or stone aggregate (not dried)	140	12.0	—	*0.08*		
Stucco	116	5.0	—	*0.20*		
MASONRY UNITS						
Brick, common[i]	120	5.0	—	*0.20*	—	0.19
Brick, face[i]	130	9.0	—	*0.11*	—	
Clay tile, hollow:						
1 cell deep 3 in.	—	—	1.25	—	*0.80*	0.21
1 cell deep 4 in.	—	—	0.90	—	*1.11*	
2 cells deep 6 in.	—	—	0.66	—	*1.52*	
2 cells deep 8 in.	—	—	0.54	—	*1.85*	
2 cells deep 10 in.	—	—	0.45	—	*2.22*	
3 cells deep 12 in.	—	—	0.40	—	*2.50*	

Thermal Properties of Typical Building and Insulating Materials—(Design Values)[a]

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[b] (R) Per inch thickness (1/k)	Resistance[b] (R) For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Concrete blocks, three oval core:						
Sand and gravel aggregate . . . . 4 in.	—	—	1.40	—	*0.71*	0.22
. . . . 8 in.	—	—	0.90	—	*1.11*	
. . . . 12 in.	—	—	0.78	—	*1.28*	
Cinder aggregate . . . . 3 in.	—	—	1.16	—	*0.86*	0.21
. . . . 4 in.	—	—	0.90	—	*1.11*	
. . . . 8 in.	—	—	0.58	—	*1.72*	
. . . . 12 in.	—	—	0.53	—	*1.89*	
Lightweight aggregate . . . . 3 in.	—	—	0.79	—	*1.27*	0.21
(expanded shale, clay, slate . . . . 4 in.	—	—	0.67	—	*1.50*	
or slag; pumice) . . . . 8 in.	—	—	0.50	—	*2.00*	
. . . . 12 in.	—	—	0.44	—	*2.27*	
Concrete blocks, rectangular core.[e,j]						
Sand and gravel aggregate						
2 core, 8 in. 36 lb.[k,e]	—	—	0.96	—	*1.04*	0.22
Same with filled cores[l,e]	—	—	0.52	—	*1.93*	0.22
Lightweight aggregate (expanded shale, clay, slate or slag, pumice):						
3 core, 6 in. 19 lb.[k,e]	—	—	0.61	—	*1.65*	0.21
Same with filled cores[l,e]	—	—	0.33	—	*2.99*	
2 core, 8 in. 24 lb.[k,e]	—	—	0.46	—	*2.18*	
Same with filled cores[l,e]	—	—	0.20	—	*5.03*	
3 core, 12 in. 38 lb.[k,e]	—	—	0.40	—	*2.48*	
Same with filled cores[l,e]	—	—	0.17	—	*5.82*	
Stone, lime or sand	—	12.50	—	*0.08*	—	0.19
Gypsum partition tile:						
3 × 12 × 30 in. solid	—	—	0.79	—	*1.26*	*0.19*
3 × 12 × 30 in. 4-cell	—	—	0.74	—	*1.35*	
4 × 12 × 30 in. 3-cell	—	—	0.60	—	*1.67*	
METALS (See Chapter 37, Table 3)						
PLASTERING MATERIALS						
Cement plaster, sand aggregate	116	5.0	—	*0.20*	—	0.20
Sand aggregate . . . . 0.375 in.	—	—	13.3	—	*0.08*	0.20
Sand aggregate . . . . 0.75 in.	—	—	6.66	—	*0.15*	0.20
Gypsum plaster:						
Lightweight aggregate . . . . 0.5 in.	45	—	3.12	—	*0.32*	
Lightweight aggregate . . . . 0.625 in.	45	—	2.67	—	*0.39*	
Lightweight agg. on metal lath . . . . 0.75 in.	—	—	2.13	—	*0.47*	
Perlite aggregate	45	1.5	—	*0.67*	—	0.32
Sand aggregate	105	5.6	—	*0.18*	—	0.20
Sand aggregate . . . . 0.5 in.	105	—	11.10	—	*0.09*	
Sand aggregate . . . . 0.625 in.	105	—	9.10	—	*0.11*	
Sand aggregate on metal lath . . . . 0.75 in.	—	—	7.70	—	*0.13*	
Vermiculite aggregate	45	1.7	—	*0.59*	—	
ROOFING						
Asbestos-cement shingles	120	—	4.76	—	*0.21*	0.24
Asphalt roll roofing	70	—	6.50	—	*0.15*	0.36
Asphalt shingles	70	—	2.27	—	*0.44*	0.30
Built-up roofing . . . . 0.375 in.	70	—	3.00	—	*0.33*	0.35
Slate . . . . 0.5 in.	—	—	20.00	—	*0.05*	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	*0.94*	0.31
SIDING MATERIALS (ON FLAT SURFACE)						
Shingles						
Asbestos-cement	120	—	4.75	—	*0.21*	
Wood, 16 in., 7.5 exposure	—	—	1.15	—	*0.87*	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	*1.19*	0.28
Wood, plus insul. backer board, 0.3125 in.	—	—	0.71	—	*1.40*	0.31
Siding						
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	*0.21*	0.24
Asphalt roll siding	—	—	6.50	—	*0.15*	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	*1.46*	0.35
Wood, drop, 1 × 8 in.	—	—	1.27	—	*0.79*	0.28
Wood, bevel, 0.5 × 8 in., lapped	—	—	1.23	—	*0.81*	0.28
Wood, bevel, 0.75 × 10 in., lapped	—	—	0.95	—	*1.05*	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.59	—	*0.59*	0.29
Wood, medium density siding, 0.4375 in.	40	1.49	—	*0.67*		0.28

Thermal Properties of Typical Building and Insulating Materials—(Design Values)[a]

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[b] (R) Per inch thickness (1/k)	Resistance[b] (R) For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Aluminum or Steel[m], over sheathing						
Hollow-backed	—	—	1.61	—	*0.61*	0.29
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	*1.82*	0.32
Insulating-board backed nominal 0.375 in., foil backed			0.34		*2.96*	
Architectural glass	—	—	10.00	—	*0.10*	0.20
WOODS						
Maple, oak, and similar hardwoods	45	1.10	—	*0.91*	—	0.30
Fir, pine, and similar softwoods	32	0.80	—	*1.25*	—	0.33
Fir, pine, and similar softwoods 0.75 in.	32	—	1.06	—	*0.94*	0.33
1.5 in.		—	0.53	—	*1.89*	
2.5 in.		—	0.32	—	*3.12*	
3.5 in.		—	0.23	—	*4.35*	

Coefficients of Transmission (*U*) of Windows, Skylights, and Light Transmitting Partitions

These values are for heat transfer from air to air, Btu/(hr ft² F). To calculate total heat gain including solar transmission, see Chapter 28.

PART A—VERTICAL PANELS (EXTERIOR WINDOWS, SLIDING PATIO DOORS, AND PARTITIONS)—FLAT GLASS, GLASS BLOCK, AND PLASTIC SHEET

Description	Exterior[a] Winter	Exterior[a] Summer	Interior
Flat Glass[b]			
single glass	1.10	1.04	0.73
insulating glass—double[c]			
0.1875-in. air space[d]	0.62	0.65	0.51
0.25-in. air space[d]	0.58	0.61	0.49
0.5-in. air space[e]	0.49	0.56	0.46
0.5-in. air space, low emittance coating[f]			
e = 0.20	0.32	0.38	0.32
e = 0.40	0.38	0.45	0.38
e = 0.60	0.43	0.51	0.42
insulating glass—triple[c]			
0.25-in. air spaces[d]	0.39	0.44	0.38
0.5-in. air spaces[g]	0.31	0.39	0.30
storm windows			
1-in. to 4-in. air space[d]	0.50	0.50	0.44
Plastic Sheet			
single glazed			
0.125-in. thick	1.06	0.98	—
0.25-in. thick	0.96	0.89	—
0.5-in. thick	0.81	0.76	—
insulating unit—double[c]			
0.25-in. air space[d]	0.55	0.56	—
0.5-in. air space[e]	0.43	0.45	—
Glass Block[h]			
6 × 6 × 4 in. thick	0.60	0.57	0.46
8 × 8 × 4 in. thick	0.56	0.54	0.44
—with cavity divider	0.48	0.46	0.38
12 × 12 × 4 in. thick	0.52	0.50	0.41
—with cavity divider	0.44	0.42	0.36
12 × 12 × 2 in. thick	0.60	0.57	0.46

PART B—HORIZONTAL PANELS (SKYLIGHTS)—FLAT GLASS, GLASS BLOCK, AND PLASTIC DOMES

Description	Exterior[a] Winter[i]	Exterior[a] Summer[j]	Interior[f]
Flat Glass[c]			
single glass	1.23	0.83	0.96
insulating glass—double[c]			
0.1875-in. air space[d]	0.70	0.57	0.62
0.25-in. air space[d]	0.65	0.54	0.59
0.5-in. air space[c]	0.59	0.49	0.56
0.5-in. air space, low emittance coating[f]			
e = 0.20	0.48	0.36	0.39
e = 0.40	0.52	0.42	0.45
e = 0.60	0.56	0.46	0.50
Glass Block[h]			
11 × 11 × 3 in. thick with cavity divider	0.53	0.35	0.44
12 × 12 × 4 in. thick with cavity divider	0.51	0.34	0.42
Plastic Domes[k]			
single-walled	1.15	0.80	—
double-walled	0.70	0.46	—

PART C—ADJUSTMENT FACTORS FOR VARIOUS WINDOW AND SLIDING PATIO DOOR TYPES (MULTIPLY *U* VALUES IN PARTS A AND B BY THESE FACTORS)

Description	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All Glass[l]	1.00	1.00	1.00
Wood Sash—80% Glass	0.90	0.95	0.90
Wood Sash—60% Glass	0.80	0.85	0.80
Metal Sash—80% Glass	1.00	1.20[m]	1.20[m]
Sliding Patio Doors			
Wood Frame	0.95	1.00	—
Metal Frame	1.00	1.10[m]	—

APPENDIX F

APPENDIX F

SUMMARY OF INTERVIEW GUIDE SHEET

Questions

1. Determine if any builder characteristic might have an effect on the use of energy-efficient features in new construction?

   a. Number of housing units constructed in 1982 ______

   b. Number of employees employed full or part-time. ______

   c. Executive characteristics

      - age ______
      - education ______
      - experience in home building ______

   d. Attitude toward energy and policy

      - very concerned ______
      - concerned ______

   e. Incentive, pricing and regulatory policies

      - for ______
      - opposed ______

   f. Use of subcontractors

	Own Employees	Own Employees and Subcontractors	Sub-Contractors
- electrical	______	______	______
- framing	______	______	______
- grading the lot	______	______	______
- HVAC	______	______	______
- insulation	______	______	______
- landscaping	______	______	______
- marketing & sales	______	______	______
- plumbing	______	______	______

g. Responsibility for HVAC and insulation decisions.

- HVAC	Builder Specifies	Joint Decision	Subcontractor Specifies
- type	______	______	______
- capacity	______	______	______
- Insulation			
- type	______	______	______
- capacity	______	______	______

h. New recent houses built.

- style ______
- size ______
- price ______
- basic features

i. Energy-efficient features utilized.

- HVAC equipment features
- construction features affecting heat loss/gain

j. Energy-conservation features added to next house if conditions warranted

2. What was it that stimulated you, the home builder, to consider using certain energy features in your new house?

3. What do you perceive as the most important reason why a consumer would resist certain energy features?

4. What criteria might you use in making your final decision to use certain energy features?

5. What do you think might be some of the risk factors in using energy-efficient features? (Hand the builder five

risks on slips of paper and tell the builder to rank them from 1 to 5, 1 being the most important and 5 the least important.)

RISKS:
- Problems in getting features properly installed
- Incurring higher costs than expected
- Having to respond to consumer complaints after the sale
- Delay in getting the house completed
- Difficulty in selling the house.

6. What are your suggested steps to insure a tighter more energy-efficient house?

7. What do you feel is your biggest obstacle in building an energy-efficient house?

8. What were the insulation values of the walls and ceilings of your most recent house constructed?

R value ______ ceiling
R value ______ walls

9. How much did the energy features add to the monthly mortgage payment of your latest house and with this investment, how much did the buyer save on utility bills per month?

10. In order to qualify a buyer for your next house, would you cut insulation to save costs?

yes ______
no ______

APPENDIX G

APPENDIX G

A METHOD FOR SELECTION OF COST-EFFECTIVE ENERGY CONSERVATION FIGURES

One of the key features in the life-cycle cost method in relation to present value is the period of years of analysis. Energy-conserving features may last up to 50 to 100 years, and the energy features are sensitive to the number of years analyzed. For example, with a mortgage interest rate of 12 percent and a 10 percent annual increase in the price of fuel, the present value of $1.00 of energy savings in the first year is $2.89 when the period analyzed is three years; $4.74 for five years, $6.52 for seven years, $9.07 for 10 years and $16.64 for 20 years using the following formula.

$$p = s \times \frac{a\,(a^n - 1)}{a - 1} \text{ if } f \neq i \qquad \text{Equation 1}$$

p = present value or added cost of energy feature.

s = operating cost savings in the first year from the added energy feature.

n = period of year analyzed or time to recoup investment.

$a = \frac{1 + f}{1 + i}$

f = estimated percentage fuel increase per year as a decimal

i = mortgage interest rate expressed as a decimal.

$$p = s \times n \text{ if } f = i \qquad \text{Equation 2.}$$

The number of years analyzed is important to both the builder and the buyer: to the builder for marketing and to the buyer in being able to pay. According to the National Association of Home Builders, seven years is a reasonable period.

In determining the time to recoup an investment, the following equations are used.

$$n = \frac{\text{LOG}\ \frac{p\ (a-1)}{s} + a}{\text{Log } a} - 1 \text{ if } f \neq i \qquad \text{Equation 3}$$

$$N = \frac{p}{s} \text{ if } f = i \qquad \text{Equation 4}$$

In using equation 3 with natural gas heat let;

p = \$140.00 added cost in going from R13 to R30 blown-in ceiling insulation.

$$s = \frac{\text{change in U x area x 24 hours x degree days x cost/therm}}{\text{100,000 x efficiency of furnace.}}$$

$$= \frac{.044 \times 1400 \text{ sf} \times 24 \text{ hours} \times 6909 \times \$.52}{100{,}000\ (.80)} = \$66.30$$

$$u = \frac{1}{r}$$

$$a = \frac{1.10}{1.12}$$

n = number of years to recoup an investment

$$= \frac{\text{Log}\ \frac{\$140\ (.9821428 - 1)}{\$66.39} + .9821428}{\text{Log}\ (.9821428)} - 1$$

$$\frac{\text{Log } (.94444865)}{\text{Log } (.98214280)}$$

$$= \frac{.0248042}{.0078253} = 3.16 \qquad - 1 = 2.16 \text{ years}$$

In the above example, 2.16 years is the time it takes to recoup the investment.

To make the life-cycle cost method practical, certain assumptions are made according to the National Association of Home Builders (1978). The salvage value at the end of the years analyzed is not included due to the reason most depreciating items' salvage value is almost zero at the end of their useful life, like mechanical/electrical equipment. For most of the other energy-efficient features, their salvage value appreciates along with the house, which would justify added first-cost expenditures.

The area of operating and maintenance costs is also not included due to these costs being zero (i.e., for insulation) to very low for mechanical equipment. Another reason why operating and maintenance costs are not included is that the variation between similar equipment will likely have similar operating and maintenance costs. When the equipment is completely different with a large variation in operating and maintenance costs, then such costs may need to be considered.

Another area that is ignored in the formula is the added cost of insurance because it is relatively minor and the effect of added real estate taxes, due to the increased

first cost of the added energy feature and the effect of the income tax in reducing the added cost. These are omitted because they tend to offset each other.

The National Association of Home Builders (1978) states that these simplifying assumptions are more than justified when the lifestyle can modify the savings by 20-50 percent.

The formulas above are just one method to show relative payback that can be used to develop investment payback periods for a local area. For a more in-depth explanation, see the book Designing, Building and Selling Energy-Conserving Homes published by the National Association of Home Builders of the United States, Washington, D.C. 20005.