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Cost Effective Measures of Conserving Energy in the Residential Sector in Southeast Georgia

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by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER I

INTRODUCTION

Energy consumed in the United States has doubled in the last twenty years and the use of natural gas and electricity has quadrupled. Every means possible should be considered to curtail excessive energy consumption and any amount over what is absolutely necessary can accurately be defined as waste.

Between World War II and 1971, energy prices dropped at a steady rate (See Figure I, page 2). There was a decrease in energy efficiency in the United States in 1967 and effective measures for conservation of energy were not taken. As a result fuel shortages have occurred irregularly but consistently during the recent years. Per capita energy use in the United States is now estimated to be six times the average for the rest of the world (10,p.128).

The percentage of total energy used by various sectors varies from study to study, however, the following approximations are representative: transportation - 25 percent; industry - 30 percent; residential/commercial (largely heating and cooling) - 20 percent; electrical generation - 25 percent (10,p.128). The generation of electricity becoming a higher percentage as the ratio of electricity to total energy consumed continues to increase. Between 1960 and 1970, total energy consumption grew 51 percent while electricity increased 104 percent. This is attributed to the substitution of electricity for fossil fuel combustion in space and water heating, cooking, and

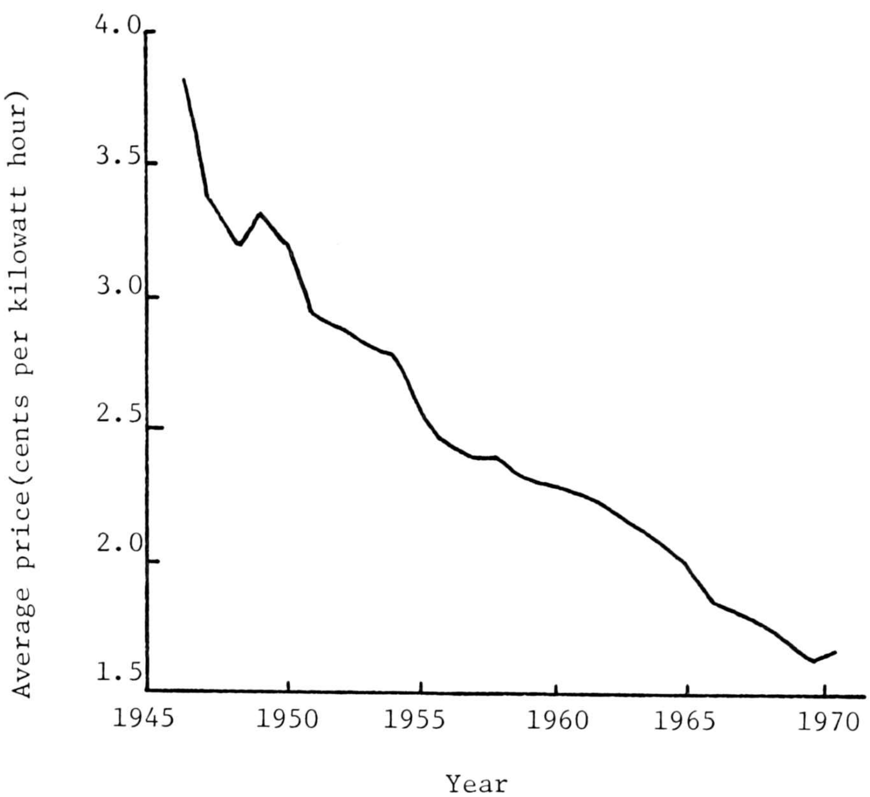

Fig. 1. Ratio of the average price of electricity to the gross national product inflation index. The average price of electricity declined relative to other prices from 1946 to 1970, but increased in 1971. Source: Electricity Démand Growth and the Energy Crisis.

industrial heat. The generation of electricity accounted for about 24 percent of energy resource consumption in 1970, as opposed to 19 percent in 1960 (22,p.480). At this writing, more than 50 percent of all electricity generated in the United States is consumed by the residential/commercial sector and almost half by industry.

More than 20 percent of the energy on the earth is used in the form of electricity. It is expected to increase to 50 percent by the end of the century. If current trends continue, it is predicted that by 1985 there will be a deficit in electrical capacity. Peak loads may actually not be reached due to limitations of output capabilities (28,p.A-6). Nuclear power is considered by many to be the only way to avoid possible future electrical shortages.

Mechanical generators driven by water power and steam are the main producers of electrical energy. Presently steam-powered generators produce approximately 85 percent of all electricity. Heat for producing steam is supplied by energy derived from fossil fuels, nuclear power, geothermal resources, and energy from solid waste (25,p.21). Fossil fuels, a non-renewable resource, are being depleted; an important reason why the cost of electricity is, and will continue to rise until alternate energy sources are developed and put into wide-scale use. By the law of supply and demand, the cost of electricity produced by the use of fossil fuels will continue to rise according to the rate of demand and the amount of remaining fuel. It can be realized that improving efficiency of energy utilization is significant in terms of cost, the environment, and resource utilization (See Table 1, p.4).

There has been debate as to whether the use of energy is largely independent of pricing and if not, what is the relationship. This relationship will affect the rate at which energy consumption will increase. Conservation will save much in the way of environment and total energy consumption in an economy that accounts for one third of the earth's annual energy use while having only 5 percent of its population. It has been pointed out that without economical fuels and electricity, neither the Houston Astrodome or mobile homes would be viable. Throughout the world, each of these would not be feasible.

The following statement concerning energy conservation was made in Energy Conservation in the International Energy Agency (19,p.8):

TABLE 1

ESTIMATED EMISSIONS OF AIR POLLUTANTS
BY WEIGHT NATIONWIDE, 1969; TOTAL 281.2 MILLION

Tons (in millions of tons/year)

	Carbon Monoxide		Particulates		Sulfur Oxides		Hydrocarbons		Nitrogen Oxides		Total
Source	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount
Automobile	111.5	74	0.8	2	1.1	3	19.8	53	11.2	46	144.4
Power Plants	1.8	1	7.2	21	24.4	73	.9	2	10.0	42	44.3
Industrial	12.0	8	14.4	41	7.5	22	5.5	15	.2	1	39.6
Refuse Burning	7.9	5	1.4	4	.2	1	2.0	5	.4	2	11.9
Miscellaneous	18.2	12	11.4	32	.2	1	9.2	25	2.0	9	41.0
Total	151.4	-	35.2	-	33.4	-	37.4	-	23.8	-	281.2

> "It is apparent that most countries are not approaching energy conservation with the same intensity and commitment applied to energy supply expansion. This is unfortunate, for there is no fundamental difference between the results of each approach. A barrel saved is as useful as a barrel produced - better in many respects."

World energy use is estimated to be 3 x 10" GJ/year and the United States accounts for 1 x 10" GJ/year. If the earth's total population consumed as much as the United States, fossil fuel reserves would last not longer than 30 years (1, pp. 1-2).

It is estimated that as much as 50 percent of United States, or one-sixth of the earth's total annual energy consumption, is lost as waste heat. Losses in the United States include two-thirds of the fuel consumed to generate electricity, five-sixths of the energy used in transportation, and close to one-third of all remaining energy (10,p. 131).

Reasons cited for such inefficiencies include: (1) the previous abundance of fuel; (2) overall public ignorance concerning energy ratings and energy conservation methods; and (3) the until-now economical cost of fuel.

It is estimated by the author of The Case For Conservation (Worldwatch, 1975) that the potential savings in energy used within the United States is as high as 50 percent. Also noted is that at current price levels, all of this potential is economic (19 p.8).

If the United States would increase its efficiency in using electricity 15 percent by the year 2000, the number of projected 1000 MWe (Megawatt electrical) generating plants could be effectively cut in number by 300 to 400. Using historical growth rates and assuming no efforts to conserve fuel or increase energy efficiency, United States generating capacity would exceed the equivalent of 2000 - 1000 MWe plants. Capital savings would be 150 to 200 billion dollars; fuel savings are approximated at 3 x 10^{10} GJ/year or 6 to 12 billion dollars per year (1, p.2).

Based on findings in Efficient Electricity Use, (4, p.807) total energy and electricity savings as high as 25 to 30 percent appear to be technically feasible. It is also esimated that United States total energy needs in the year 2000 could be cut 27 to 47 percent, and nearly half of this could be achieved by efficient use of electricity. This could reduce the amount of fuel needed by the generating plants.

Limits published in many papers are not technical or thermodynamic limits for efficiency energy use, but are based on engineering judgements of the economic viability of certain technical options. Studies indicate that potential energy savings would be greater if the laws of thermodynamics were the only constraint (19,pp. 807-808).

The Base Case is if there is no conservation or improvement in efficiency, total energy use is expected to experience a 3.25 percent growth rate (22 year doubling time) for the years 1975-2000; growth rate of electricity is expected to be 7.2 percent (10 year doubling time) (1, p.808).

Table 2, page 7, shows possible savings in the different sectors relative to the Base Case. Table 3, page 8, shows total annual energy savings (relative to the Base Case) for the year 2000; also shown is the importance and weighted annual savings for each sector. In these tables, as well as for the Base Case, all changes are at the point of end use and generation, distribution, and transmission - thus, improvements is these areas are not considered.

TABLE 2*

POTENTIAL SAVINGS WITH IMPROVED USE EFFICIENCY

Sector	Immediate (0-1 yr) Operational and housekeeping changes	Near-Term (2-5 yr) Some investments and process and equipment changes	Long-Term (5-25 yr) Major investments and process and equipment changes	Annual Savings in the year 2000
(A) US TOTAL ENERGY SAVINGS (1975-2000), IN PERCENTAGE OF SECTOR ENERGY USE COMPARED TO BASE CASE				
Industry	10-15	10-15	10-20	30-50
Commerce	5-10	5-10	5-10	15-30
Residential	5-10	10-15	10-20	25-45
Transportation	10-15	10-15	10-20	30-50
(B) US ELECTRICAL ENERGY SAVINGS (1975-2000) IN PERCENTAGE OF SECTOR ELECTRICITY USE COMPARED TO BASE CASE				
Industry	5-10	5-10	5-10	15-30
Commerce	5-10	5-10	10-20	20-40
Residential	5-10	5-10	15-25	25-45
Other**	0-5	5-10	5-10	10-25

*Includes estimated savings in agriculture
**Efficient Electricity Use (4,p.810)

TABLE 3*

POTENTIAL TOTAL ENERGY SAVINGS FOR THE UNITED STATES

Sector	Annual Savings (in percent of sector energy use) for the year 2000 (%)	Sector Importance (year 2000)** (%)	Weighted Annual Savings (in percent of total US energy use in year 2000) (%)***	Potential Savings**** (year 2000) 10^9 GJ/yr.	Mbpd
Industry	30-50	50	12-20	22-36	10-16
Commerce	15-30	15	2-5	4-9	2-4
Residential	25-45	20	5-9	9-16	4-7
Transportation	30-50	25	8-13	14-23	6-10
TOTALS	---	100	27-47	49-84	22-37

NOTES: *Efficient Electricity Use

**Estimated for year 2000

***Calculated by multiplying sector importance times annual savings.

****Based on year 2000 total energy use of 180 x 10^9 annual GJ/yr. (170 x 10^{15} Btu/yr, 80 Mbpd). This corresponds to an annual growth rate of 3.25 percent (22-year doubling time). Numbers are rounded. Table uses the conversion that 1 Mbpd = 2.24 x 10^9 GJ/yr to calculate energy use in equivalent quantities of crude oil.

The importance of electrical efficiency is due to the likelihood of an accelerated electrical consumption. Consumers are shifting from other forms of fuels to electricity, due to dwindling supplies of petroleum and natural gas. Figure 2, page 10 shows approximately how electrical energy growth compares with total energy growth on both United States and world levels.

Electrical resistance heating is reportedly being installed in one-third of all new homes and as many as 50 percent of all office buildings (1973) is considered to be 100 percent efficient. In actuality, the maximum possible (overall) end-use efficiency is only 30 percent considering a power plant efficiency of 33 percent and a 91 percent efficiency in transmission and distribution to the customer.

End-use efficiency of gas or oil-burning systems has been estimated at 60 percent. This means 1.7 units of heat must be extracted from the raw fuel for every unit of heat in the home as opposed to 3.3 units which must be extracted from fuel at the power plant for each unit in the home when electrical resistance heating is used (22,p.484). The importance of increasing the efficiency of electricity is a particular concern.

Figure 3, page 11, shows present and projected total energy consumption for the four major sectors; Figure 4, page 12, shows present and projected electrical consumption.

The Government and Energy Conservation

The United States government's involvement with energy has been developing gradually over a number of years through codes and ordinances, acts, administrative actions, and creative interpretations of existing laws. These regulatory actions have actually been by-

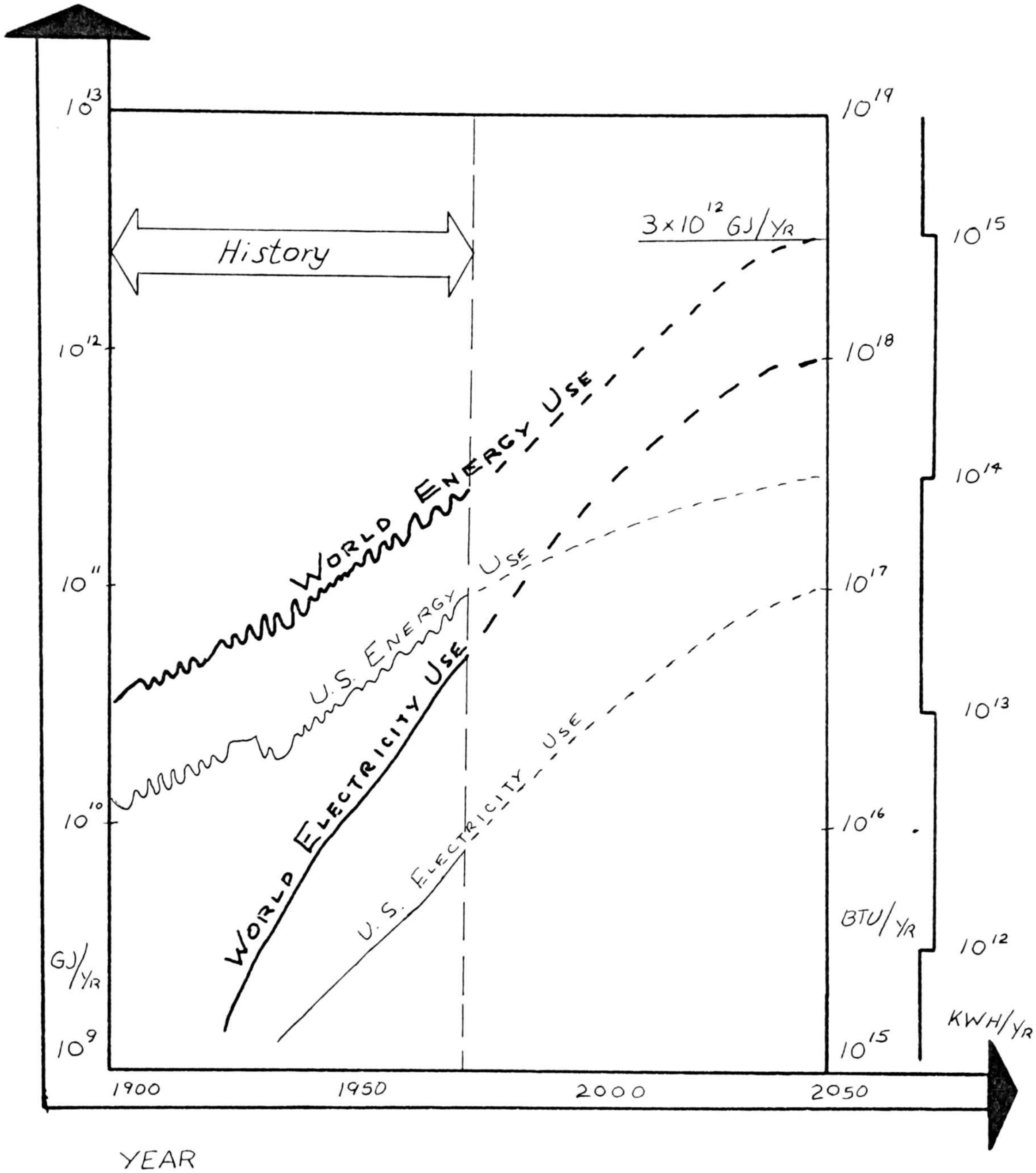

Figure 2*

Annual Energy Output
*Energy and the World of 2000 A.D.

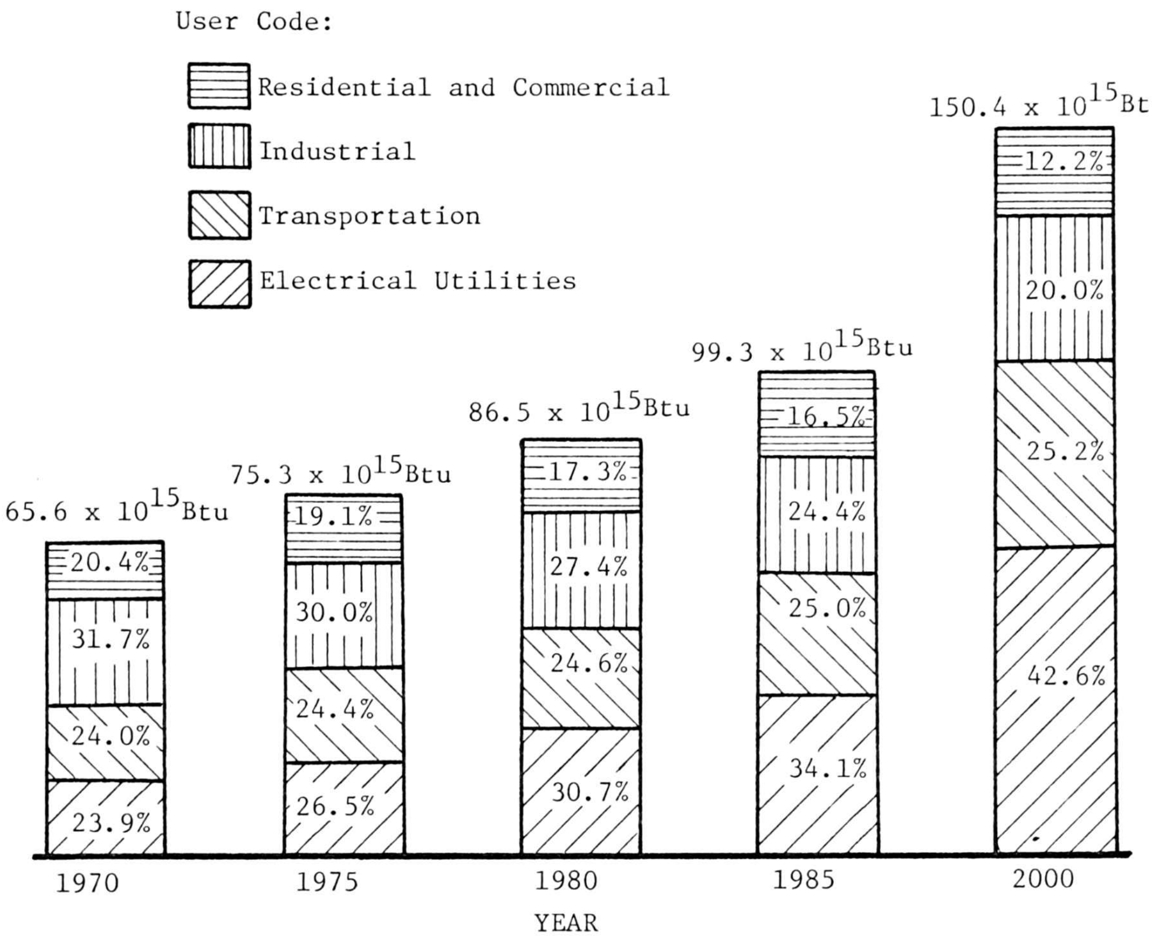

FIGURE 3*

TOTAL ENERGY (E_T) CONSUMPTION BY USER-1970, 1975, 1980, 1985, AND 2000

*The U.S. Energy Program

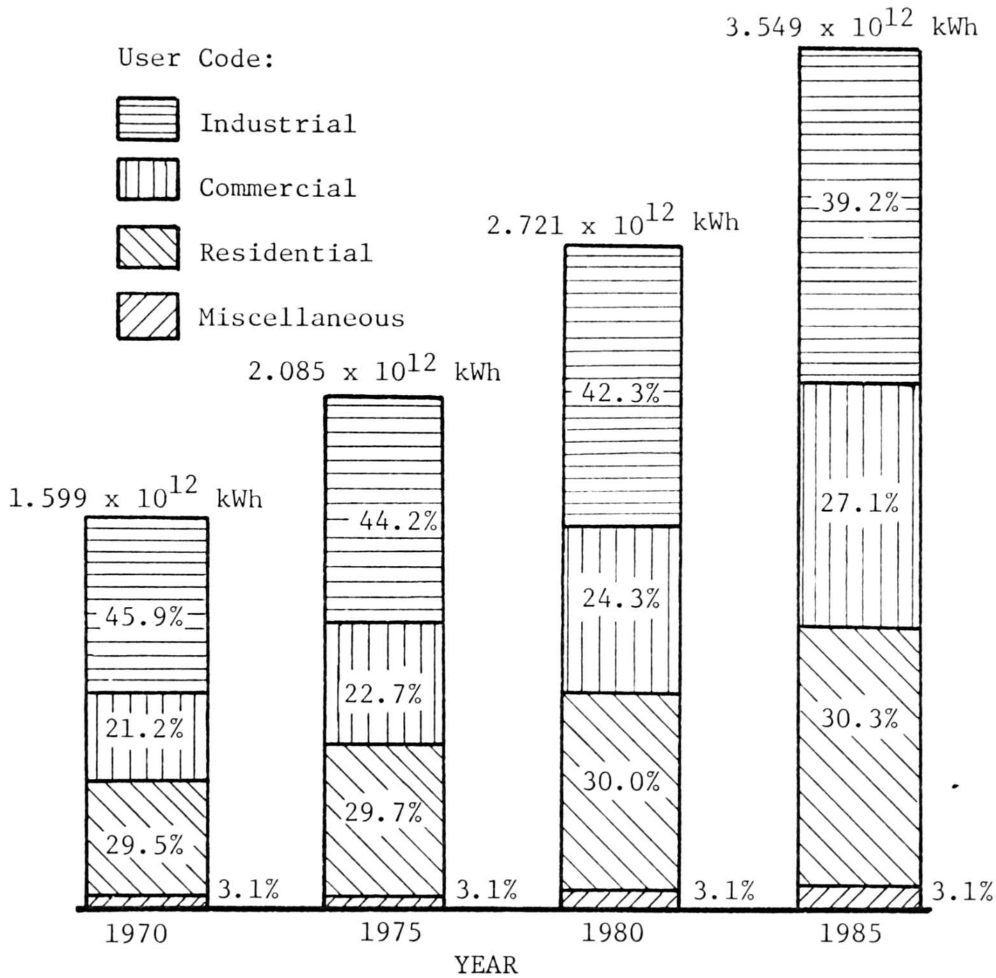

FIGURE 4*

ELECTRICAL ENERGY (E_E) CONSUMPTION BY USER-1970, 1975, 1980, AND 1985

*The U.S. Energy Problem (28)

products of governmental actions concerned with other objectives rather than real energy awareness (1, pp. 879-880). However, government involvement rapidly accelerated in 1971. On June 4, 1971, the president publicly acknowledged for the first time that the United States had a serious energy problem, and a planned program was suggested to help alleviate it. Numerous agencies were created to administer policies having specific impact on the nation's energy systems have been funded by the federal government.

In October of 1974, the president signed a bill (effective 120 days later) to abolish the Atomic Energy Commission and create the Energy Research and Development Administration (ERDA) and the Nucelar Regulatory Commission (NRC). The purpose of ERDA was to administer federal research and development projects. The Federal Energy Administration (FEA) was created in 1974 for the purpose of petroleum allocation and pricing, fuel conservation, energy data collection and analysis, and energy independency planning. The ERDA and the FEA, along with the Energy Resources Council (ERC) (whose job it was to coordinate communication among federal agencies involved with energy matters as well as to set up and implement national energy policy) began the development of a solid foundation for energy policy (1, pp. 881-882).

The major responsibilities of the FEA fall under the categories: (1) management and administration; (2) policy and analysis; (3) conservation and environment; (4) resource development; (5) operation, regulation and compliances; and (6) international affairs. The department addressing itself to conservation and environment has these goals: (1) to reduce the rate of energy demand growth; (2) implement energy conservation programs; and (3) promote the efficient use of energy resources.

Similarly, ERDA is comprised of six functional jurisdictions: (1) fossil fuels; (2) nuclear energy; (3) environmental safety; (4) conservation; solar, goethermal, and (5) advanced energy systems; and national security. The ERDA "has the responsibility for conservation research and development programs including automotive power systems, end-use consumption technologies, and improving energy efficiency" (1, pp. 885-87).

President Carter's National Energy Program (NEP) called for a strong roll in conversation and large energy decreases in transportation, electric utility, and residential/commercial sectors for the years 1976-1985.

The Industrial Sector

The publication Efficient Electricity Use records that industry utilizes 40 percent of United States energy resources of which 40 percent of which is natural gas, 25 percent petroleum, 25 percent coal, and 10 percent from hydro-nuclear resources.

It is estimated that an overall energy savings of 30-50 percent could be achieved in this sector during the years 1975-2000, with a 10-15 percent immediate savings through modification involving only small financial outlay (1, pp. 25-26).

The primary method of achieving increased efficiency would be to develop an energy maintenance program as an organized means of considering such factors as energy accounting, economic analysis (benefit/cost ratio), and computer management simulation (1,pp.25-26).

The Commercial Sector

Electrical use in the commercial sector was rated at 9.6 percent annually from the years 1962-1972, was growing faster than the industrial or residential sectors. Energy consumption for this sector was 14.5 percent of the country's total in 1968. About one-third of this total was in the form of electricity, 24 percent of total United States electricity used. Primary uses in the commercial sector are for heating, air conditioning, refrigeration, lighting, and electric motors.

From the years 1975 to 2000, potential energy savings are estimated to be 15-30 percent (approximately 2 to 5 percent of total United States energy use). Primary means of achieving these savings are: (1) modification and retrofitting of existing structures and equipment; (2) better design of new equipment and building components, and (3) attention to operation and maintenance strategies (1, pp. 135-137).

The Residential Sector

As of 1971, residential energy use accounted for 22 percent of total raw energy consumption in the United States. It is estimated that from 30 to 56 percent of the energy supplied to this sector is wasted. (1-4) This waste is attributed to the following: "(1) insufficient thermal insulation; (2) undesired air infiltration; (3) excessive lamping; (4) appliance operation; (5) insufficient knowledge of power consumption facts; (6) up-to-now low cost of energy" (1, pp. 215-216).

Overall long-range savings are estimated at 25 to 45 percent of residential energy use, with a 5 to 10 percent immediate savings possible. Savings in this sector can be effected by: modifications of existing buildings, improved methods of operating strategies, and improved design of future structures.

Energy Conservation

Energy conservation is becoming increasingly important as the environmental problems of energy production increase and fuels become more and more scarce. The United States annually uses more than 63 x 10^{15} Btu's. A 1 percent savings (around one hundred million barrels of petroleum) would be significant (10,p. 131). Potential savings by conservation are estimated to extend beyond this amount.

Energy-efficient technology will be successfully implemented by through awareness of the need, acceptability and ease of understanding, and visible economic feasibility by the people. Becoming economically beneficial to conserve energy is the most important single factor to both the businessman and the individual consumer. Various studies indicate the largest energy savings (and perhaps the easiest to accomplish) could be in homes and commercial buildings which are seldom designed for energy conservation.

Accounting for more than one-fifth of the total United States energy consumption in 1971 and almost 30 percent of end-use electrical consumption in 1970, the residential sector is a major area of consumption and an important area for conservation measures.

The Problem of the Study

The purpose of this investigation was to determine the cost-effectiveness of several means of conserving energy in the residential sector in southeast Georgia. The study was concerned primarily existing housing - cost-effective measures in new building design necessarily result.

Hypothesis

The hypothesis for this study was as follows: modifications can be made to homes in the southeast Georgia area resulting in less energy consumption and a direct dollar savings to the consumer within a reasonable period of time.

Basic Assumptions

The basic assumptions of this study were as follows:

1. The cost of energy will continue to rise
2. The local climate will continue to be the same for the next several years as it has been over the past 20 years
3. The demand for energy will increase

Limitations

The limitations for this study were as follows:

1. Only tried-and-proven technology will be considered
2. The study will be confined to the southeast Georgia area
3. The study will be concerned with housing in the residential sector - apartments and mobile homes are largely ignored due to differences in construction
4. Prices quoted will be those in effect at the date of the study

Definitions and Abbreviations

The following terms are defined in alphebetical order as follows

British Thermal Units (Btu) is a measure of heat energy.

Cooling Degree Days is the number of degrees the average daily temperature is above 65^{o}F, i.e.-If the average temperature for one day is 70^{o}F, that is 5 cooling degree days.

Giga (G) is 10^9.

Heating Degree Days is the number of degrees that the average daily temperature is below 65^{o}F.

Joule - a unit of energy in the International System.

Kilo (K) is 10^3 .

Kilowatt (KW) is 10^3 Watts.

KWe is Kilowatt electrical.

Mbpd is Mega Barrels of oil per day.

R-Value is thermal resistance (1/U). Associated with insulation, the higher the R-value, the more efficient the insulation.

U-Value is thermal conductance (1/R), expressed as (Btu)/(hr)(sq.ft)(^{o}F).

Watt is a unit of measure of electrical power. It is equal to amperes times voltage.

Watt-hour is one watt used for one hour.

Summary

The United States uses approximately one-third of the earth's total energy. It is estimated that 50 percent of the energy is lost as waste heat.

Potential energy savings in the United States have been estimated as high as 47-50 percent compared with present use.

The government first committed itself to the energy problem in 1971 and since increased its role in the search for efficient use of energy. Studies indicate that the largest potential savings may be in the area of residential and commercial buildings.

The purpose of this investigation was to determine the cost-effectiveness of several methods of conserving energy in the residential sector of southeast Georgia.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Residential energy is expected to equal 23.9 percent of total United States consumption by the year 2000 (28,p.F1). Energy sources for this sector were predicted in 1970: electricity - 31 percent; gas 40-42 percent; oil - 26-28 percent; and coal and wood - 1.6 percent (28)(1); see Table 4, page 21, for a further breakdown. It is partly due to electricity, with its poor production efficiency, being such a large part of the residential supply that this sector accounts for so much of total raw energy use.

It is projected that by 1980, space conditioning will account for 63 percent of total projected residential/commercial energy consumption (22). With regard to consumption for singular uses, only transportation, at 25 percent uses more of the United States total than that of combined residential/commercial space heating; overall industrial use accounted for 42 percent while the other 15 percent went to uses (besides space heating) in the residential/commercial sector. Space heating and cooling, water heating, refrigeration, and cooking account for 85 percent of residential energy consumption (75 percent of commercial use), leaving appliances lighting, machinery, and other uses to account for the rest (22).

TABLE 4*

RESIDENTIAL ENERGY USAGE, 1970

			Percent of	
	Btu/yr / 10^{15}	kWh/yr / 10^{9}	Residential Energy Use	Total U.S. Energy Use
Space Heating				
Natural Gas[a]	4.928		34.1	7.5
Oil[b]	3.988		27.6	6.1
Coal & Wood	0.224		1.6	0.3
Electricity	0.244[c]	23.6	1.7	0.4
Totals	9.384		65.0	14.3
Water Heating				
Natural Gas	0.654		4.5	1.0
Electricity	1.255	121.4	8.7	1.9
Totals	1.909		13.2	2.9
Lighting & Home[d] Appliances				
Electricity	1.462	141.4	10.1	2.2
Totals	1.462		10.1	2.2
Space Cooling				
Natural Gas	0.00716		0.05	0.01
Electricity	0.751	72.6	5.2	1.2
Totals	0.758		5.2	1.2

(continued next page)

TABLE 4 - Continued

	Btu/yr / 10^{15}	kWh/yr / 10^{9}	Percent of: Residential Energy Use	Percent of: Total U.S. Energy Use
Cooking				
Natural Gas	1.179		1.2	0.3
Electricity	0.485	46.9	3.4	0.7
Totals	0.664		4.6	1.0
Clothes Drying				
Natural Gas	0.0226		0.2	0.03
Electricity	0.025	24.2	1.7	0.4
Totals	0.273		1.9	0.4
All Domestic Use				
Natural Gas	5.791		40.0	8.8
Oil	3.988		27.6	6.1
Coal & Wood	0.224		1.6	0.3
Electricity	4.447	430.8	30.8	6.8
Totals	14.450		100.0	22.0

*The U.S. Energy Problem

[a]Includes LPG

[b]Excludes LPG and manufactured gas; latter is included in original source.

[c]Thermal equivalent at 10,340 Btu/kWh heat rate

[d]Excludes water heating, cooking and clothes drying

If energy consumed within a household is defined as the difference between the inflow to do work and the outflow after that work is done, the energy flow into and out of a household can be represented by Figure 5. Wasted energy in the home is estimated to be over 30 percent (1) and as much as 56 percent (28) of total input; of this loss, 79 percent is to the environment and considered highly controllable (28). If it is assumed that space heating accounts for approximately 65 percent of residential energy input, it is proportionally responsible for 79 percent of the waste (28). Water heating is another area of large potential savings in the home, it has been variously estimated that consumption for this purpose is around 13.2-15 percent of the residential total, or 3 percent of total United States energy use (and 4 percent of the United States total in residential and commercial) (8) (18) (28). Table 5, page 24, illustrates potential savings in the residential sector; over a 2-16 year period the change is estimated to be 30 percent.

RESIDENTIAL ENERGY FLOW

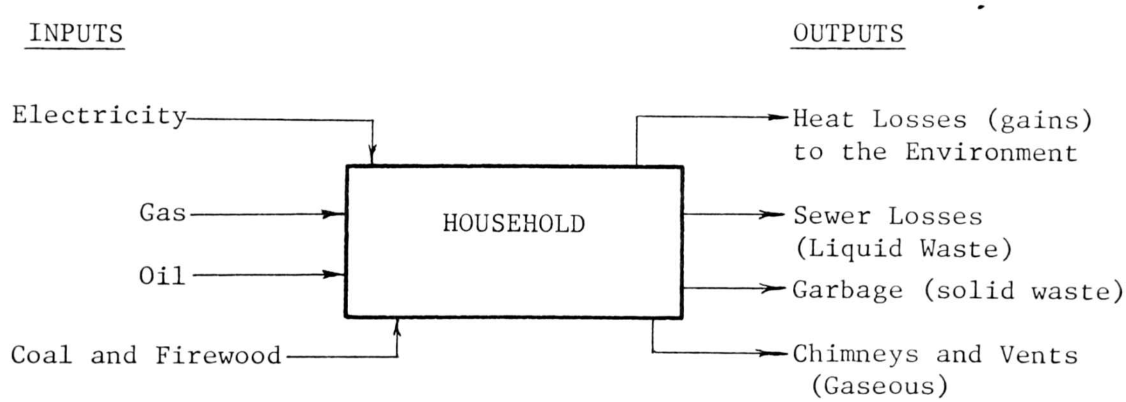

Figure 5*

*The United States Energy Problem

TABLE 5*

PRE-1974 HOMES: POSSIBLE REDUCTIONS IN ENERGY REQUIRED FOR SPACE HEATING

Source of Savings	Action Required	Probable Savings/ Unit	Percent Units Applicable	Assumed % Compliance	Time Frame	Percent Per Year	Savings Total
1. Reduce Conduction, Convestion a. Insulation	Insulate ceiling, crawl space & improve insulation where marginal.	15%	50	80	4 yrs.	1.5	6.0
b. Convection	Storm windows, weather strip doors, seal cracks.	10%	50	80	4 yrs.	1.0	5.0
2. Heating plant a. Heating system	Install more efficient heating system, p.e. switch operated electric starter, insulate ducts, etc.	10%	70	8C	16 yrs.	0.3	3.0 (10 yrs.)
b. Maintenance & repair	Maintain & repair heating systems clean filters, etc.	15%	70	80	2 yrs.	4.2	8.4
3. Personal & family habits. a. Temperature reduction	Lower temperature 1+° during day; 10° during night	4-5% for day; 6% for night	Day 100% Night 60%	80 80	2 yrs. 2 yrs.	2.0 1.4	4.0 2.8

TABLE 5 - Continued

Source of Savings	Action Required	Probable Savings/ Unit	Percent Units Applicable	Assumed % Compliance	Time Frame	Percent Per Year	Savings Total
4. other habits	a. Handling blinds & drapes in unoccupied rooms b. Closing dampers when fireplace is not used c. Closed door discipline d. Other conservative measures	6%	8	80	2 yrs.	1.8	3.6

*Projecting the Impact of Energy Conservation Measures in the Home

Annual savings in the residential sector in the year 2000 are estimated to be 25-45 percent of total energy and 25-45 percent of electrical energy, as shown in Table 6, p.26. A United States government study indicates a potential savings in the residential/commercial sector of 10 percent short term (immediate), 14 percent mid-term, and 30 percent long term (1).

TABLE 6*

Potential Savings in Residential Energy Use

Period	Potential Savings (%) Total Energy	Potential Savings (%) Electricity
Immediate--Operational Housekeeping changes	5-10	5-10
Near-Term--Some investments and process equipment changes	10-15	5-10
Long-Term--Major investments and process and equipment changes	10-20	15-25
Annual savings--in the year 2000	25-45	25-45

*Efficient Electricity Use

Space Conditioning

Heating

Over 50 percent of the energy delivered to total-electric homes in a moderate climate is used for space heating. In homes heated with oil or gas, this fraction is higher due to the fact that thermal insulation has not previously been stressed as much where these fuels are used (22,p.483). Because a large percentage of energy is used for space heating, space must be investigated for potential savings. Three methods for achieving these savings are: (1) improved construction techniques (or retrofitting existing housing); (2) increased the efficienty of the heating system (or air conditioning system in the case of cooling), and (3) efficient operating techniques through awareness and understanding by individuals. Many of the same measures which cut down on space heating have the same positive effect on space cooling since the goal is to keep the inside temperature isolated from and different than that of the surrounding environment.

Space heat is lost from a house primarily in two ways: (1) heat transmission through ceilings, walls, doors, windows, and floors; and (2) air infiltration (into the house) through cracks around doors and windows, and through open doors (28,p.F-10). With a given set of conditions, the temperature difference between outside and inside determine how severe these losses will be. These conditions help determine how much insulation is economically feasible to the homeowner.

An analytical expression for the cost of heating a building is given in this equation by Hottel and Howard:

Seasonal Heating cost (\$/yr) =

Fuel cost + capital cost + maintenance cost

This assumes the maintenance of a constant temperature level (27,p.21).

If a fixed temperature is assumed, the components of the above equation may be further broken down. All factors can't be quantified exactly in this particular equation given, thus preventing mathematically optimizing for minimum cost. However, the various different ways in which energy can be reduced are clearly shown. The expression for fuel cost is as follows:

$$\text{Fuel Cost} = \frac{0.024F}{E}\,(D(\Sigma AU+cn)-g)$$

Where: E is the thermal efficiency of the fuel being used, expressed as a percentage.

F is the fuel cost in $\$/10^5$ Btu.

D is the degree days/yr. It is assumed that no heating is needed when the average outside temperature exceeds 65^oF. When the average is lower than this, the differer is taken between the average and 65^oF. The sum of all differences gives the degree days/yr.

ΣAU is the sum of each area (A) multiplied by the heat transfer coefficient (U) ('U-Values') of that area, making up the external cover/skin of the building, in Btu/^oF/hour

C is the heat capacity of the air within the building in Btu/^oF (0.018 x volume in $Ft.^3$)

n is the number of air changes in the building per hr.

g is the heat gain from sources other than the heating system: appliances, solar gain, and others in Btu/yr.

The Capital cost in the initial equation may be expressed as Ci/100.

Where: C is the capital expenditure, in dollars, on the heating system, including insulation and all other heat-saving features on the building

i is the interest, plus depreciation, on the capital investment, expressed as %/yr.

Maintenance cost is expressed in dollars per year (27,pp.21-22).

Factors affecting energy consumption in a residence include the following: (1) thermal efficiency of the fuel; (2) fuel cost; (3) the number of degree days; (4) the outside area of the structure; (5) the heat transfer coefficient (U-value) of the outside area; (6) the heat capacity of the air within the building; (7) the number of air changes within a given time (generally per hour); and (8) the heat gain from sources other than the heating system (27,pp. 21-26). Other influencing factors include the thermal mass of the structure, the amount of wind to which the structure is exposed, and maintenance of the building (the heating system in particular). It is generally accepted that insulation is the single most important factor in building construction that can give immediate and substantial benefits in energy savings. This is readily seen in the heating cost equation where fuel cost is directly proportional to ΣAU.

If a building is constructed of materials having a high thermal mass, heat is retained during the day and released during the night, thus damping (to some degree) the great temperature swings. The effective R-value is decreased (U-value increased) by an amount proportional to the wind speed to which it is subjected. According to Victor Olgyay, a twenty miles per hour wind can double the heat load of a house for which five miles per hour winds are the norm (27,p. 30). A heat pump run by electricity and averaging two units of heat for every unit of electrical input would equalize fuel consumption for gas, oil and electric heating; this is a realistic output for heat pumps. Other sources say that heat pumps can be used two and one-half to six times as effectively as resistance heating (27,p. 47). A current article states that more advanced heat pumps may require about 40 percent as much electricity as resistance heating (12, p. 851).

With oil-burning heating systems, extensive tests have shown that the average residential furnace uses approximately 15 percent more fuel than necessary because of improper adjustments or $50-$75 more per year for the consumer. Gas furnaces also suffer inefficiencies due to improper adjustments, however, they are not as wasteful as oil burners (8, p. 267).

J. C. Moyers of the Oak Ridge National Laboratory (ORNL), did a hypothetical study using model homes (1800 square feet) in three climactic regions, (Atlanta, New York, and Minneapolis), each representing one-third of the United States. His study in 1970-71, "Finds that additional insulation in walls and ceilings, weather stripping, foil insulation on floors, and in some regions, storm windows, can be economically justified" (10,p. 132). The nation-wide average reduction of energy use using the economically optimum amount of insulation would be 43 percent for gas heated homes and 41 percent for electrically heated homes or 4.6 percent of the nation's energy consumption in the year 1970 (22,p. 484).

Table 7, p. 31, shows the results of Moyers' study in the New York Home. Savings shown are given after the costs of insulation installation have been recovered, and would be realized annually for the lifetime of the building. A 7 percent mortgage interest rate was assumed (17).

It is noted that the revised minimum property standards save an appreciable amount of energy and cost in heating a residence. It

TABLE 7*

COMPARISON OF INSULATION REQUIREMENTS AND MONETARY AND ENERGY SAVINGS FOR A NEW YORK RESIDENCE

Insulation Specification	Unrevised MPS[a]		Revised MPS[a]		Economic Optimum	
	Gas	Electric	Gas	Electric	Gas	Electric
Wall insulation thickness (inches)	0	1.875	1.875	1.875	3.500	3.500
Ceiling insulation thickness (inches)	1.875	1.875	3.500	3.500	3.500	6
Floor insulation	No	No	Yes	Yes	Yes	Yes
Storm windows	No	No	No	No	Yes	Yes
Monetary Savings (dollars per year)	0	0	28	75	32	155
Reduction of energy consumption (percent)	0	0	29	19	49	47

*Perspectives on Energy

[a]Minimum property standards (MPS) for one and two living units.

does not minimize long-term cost to the homeowner. Increasing this requirement (of insulation) would increase both energy and dollar savings.

It was estimated by the National Bureau of Standards that improvements in construction and insulation can reduce energy consumption for space heating and cooling by 40-50 percent over 1973 norms (22,pp. 497-98). Potential savings from both residential and commercial buildings amount to approximately 7 percent of total national energy use (10,p. 133).

A study by the National Mineral Wool Insulation Institute's technical committee found a maximum energy savings between 1973 and

1982 to be 2780 Trillion Btu's, however, this was considered an unobtainable figure due primarily to the difficulty of converting older homes and buildings. About half of this figure was believed to be an approachable figure; cumulative savings were estimated at 17.1 billion dollars with an actual cost to the consumer of 6.4 billion dollars (5, p. 186). The institute believed that were a program successfully implemented, 70 percent of the gap in gas availability predicted for the year 1982 by the Federal Power Commission (FPC) could be made up and 90 percent of the gap predicted for the year 1990 (5, p. 186).

In a 1961 study by the Wood Conversion Company, two single story houses in St. Paul, Minnesota were specially instrumented, well insulated, equipped with double windows and doors, and set with a ventilation rate of one change per hour. The houses were not occupied. The opening and shutting of doors, the production of body heat, heat from electric lights, and the use of appliances, were all simulated. The winter heat losses were recorded to be 15 percent through the walls, 13 percent through the roof, 5 percent through the floor, 27 percent through doors and windows, and 40 percent through air changes (27, pp. 31-32). Further information on actual insulations with other pertinent data were not located.

Air conditioning

Air conditioning is the third largest energy consuming function in a total electric residence, falling behind space heating and water heating. It is a particularly important consideration because it is a primary contributor tothe annual peak load occuring during the summer for many utilities. In John Moyers' study, the economically optimum amount of insulation in his New York model resulted in an energy reduction for air conditioning of 27 percent for gas homes and 18 percent for electric homes as compared with the 1970 minimum property standards (shown in Table 7,p.31). With the market saturation statistically shown to be at about 40 percent in 1970, sales are expected to continue to show a strong growth pattern (sales growth had a doubling time of 5 years from 1960 to 1970) (22,p. 485). See Table 8, p.14, for 1970 saturation index for key appliances and see Appendix A for energy usage of typical household appliances.

In 1971 cooling efficiencies ranged from 4.7 to 12.2 Btu's per watt-hour for room air conditioners. The least efficient machine would use 2.6 times as much electricity as the most efficient one per unit of cooling (22,p. 484). This is a prime example of where increased efficiencies of appliances would save a tremendous amount of energy.

It is recognized that large central air-conditioning and heating plants can use as much as 10-15 percent less energy than decentralized package units. This is very dependent on the layout and pattern of use of the building since decentralized units can be locally controlled and switched off when not needed (27,p. 45). Michael Corr of the American Association for the Advancement of Science Committee on Environmental Alterations calculated that if all air conditioners had been designed for their (1974-75) maximum efficiency, a 36 percent overall energy savings could have been achieved (27,p. 45).

The Association of Home Appliance Manufacturers started requiring that all window air-conditioning units be labeled in 1973 allowing consumers to compute life-cycle operating costs. The units are rated using their "Energy Efficiency Ratio" or EER - the Btu's of cooling capacity divided by the wattage of the unit. Thus, the higher

TABLE 8*

APPLIANCE SATURATION AND AVERAGE ANNUAL ELECTRICITY USE

	Saturation (%)			Average annual use in households having the appliance (kWh/household)		
	1950	1960	1970	1950	1960	1970
Refrigerators	82.8	98.1	99.8	345	780	1,300
Air Conditioning						
Room	0.8	10.9	26.5	1,402	1,663	1,946
Central	0.1	1.94	11.3	3,560	3,560	3,560
Lighting	100.0	100.0	100.0	500	600	750
Space Heating	0.7	1.8	7.6	10,000	12,945	14,588
Water Heating	10.9	21.0	25.2	3,675	4,010	4,500
Clothes Drying	1.05	12.3	29.1	520	935	993
Ranges	16.2	31.7	40.3	1,250	1,225	1,175
Television	12.9	90.1	94.7	290	335	417
Food Freezers	6.2	19.0	28.0	620	888	1,384
Clothes Washers	73.6	75.9	70.5	45	60	363
Dishwashers	1.7	6.7	18.9	120	347	363
Irons	79.8	88.5	99.6	110	132	144

*Residential Consumption of Electricity, 1950-1970.

the EER (number), the more efficient the unit. Hopefully the average consumer will utilize this information to determine which unit is actually cheaper to own over its lifetime. Generally this proves to be the most efficient unit even though initial cost is higher.

An alternative or supplement to air conditioning might be the installation of a large fan in the ceiling located centrally within the home. Anytime the outside air is cooler than the temperature inside, the fan can be turned on and the entire house will be cooled. There are many times when such a unit can be used instead of the air conditioning and the cost to run a small motor is minimal.

Windows

Windows are an important source of heat gain or loss with principal building skin losses through them anytime they comprise more than 25 percent of the total area. Generally, window losses comprise 10-20 percent of a buildings total loss. One study shows that about half the heat loss through the walls in an 1100 square foot ($100m^2$) home is through the windows (1).

Heat loss from windows can be cut in half with the use of storm windows. It has been calculated that (at 60 percent interest) an investment in storm windows in most areas of the country would pay for itself in 10 years - after that, the energy/dollars saved is all profit to the homeowner (5, p. 183). Table 9, p. 36, shows thermal losses through windows of various types with both wooden and metal casings.

"For glazing systems using heat reflective glasses with metallic surface coatings of low emissivity, the metallic coating improves the heat loss (as much insulation improvement as 30-40 percent for double glazed units)" (1, p. 24). Where this type of window is employed, aluminum

TABLE 9*

BUILDING HEAT LOSSES THROUGH WINDOWS

(a)

Glazing system	Degree of exposure: Sheltered	Normal	Severe
Single	5.0	5.6	6.7
Double			
air space 3 mm wide	3.6	4.0	4.4
6 mm	3.2	3.4	3.8
12 mm	2.8	3.0	3.3
20 mm (or more)	2.8	2.9	3.2
Triple			
Each air space 3 mm wide	2.8	3.0	3.3
6 mm	2.3	2.5	2.6
12 mm	2.0	2.1	2.2
20 mm (or more)	1.9	2.0	2.1

(continued next page)

TABLE 9 - Continued

(b)

Window type	% Total Window area occupied by frame	Degree of exposure: Sheltered	Normal	Severe
Single-glazed:				
metal casement**	20	5.0	5.6	6.7
wood casement	30	3.8	4.3	4.9
Double-glazed:***				
metal horizontal sliding window with thermal break	20	3.0	3.2	3.5
wood horizontal pivot window	30	2.3	2.5	2.7

*Energy Conservation Strategies
**Metal frame assumed to have a similar thermal transmittance to that of the glass
***With 20 mm airspace

window frames would account for about 25 percent of the total thermal loss, however, wooden frames would reduce this to around 13 percent.

It should be pointed out that both double windows (or storm windows) and glazed windows are most advantageous when installed in a new building because major savings are obtained through the reduced size of air conditioning and heating systems (1, p. 178).

Internal shading can be highly beneficial in the reduction of solar transmission through windows; examples of reductions through this method with single-pane windows are: venetian blinds of medium colo provice 36 percent; light-colored venetian blinds provide 45 percent; light and translucent shades provide 75 percent. Solar gains on the east and west exposures can be effectively reduced by use of vertical baffles (1, p. 242).

Water Heaters

The production of hot water in the home accounts for 13-15 percent of total residential energy consumption and 3 percent of United States consumption (20) (18). In 1970, over 95 percent of all occupied homes had hot water systems and over 50 percent of those in the South Atlantic region were electric (18, pp. 1-2).

An increasing amount of energy has been devoted to residential water heating-primarily due to convenience and the increased influence to afford it. As the number of houses increase, so does the number of water heaters. There is more hot water being used per unit leading to an increase in the average tank size. Water heater sales center around the 50 gallon size for electric units and 40 gallons for fossil fuel units. A standard (2 inches of insulation) 50 gallon electric water heater will use about 7 percent more electricity than a similar 30 gallon unit. Heat losses through the walls of an electric 50 gallon heater are about 20 percent and about 35 percent for fossil fuel units (18).

James Mutch did a study on reducing the energy consumption of hot water heaters, part of which involved an assessment of adding insulation, results were that added insulation would cut down on fuel costs a substantial amount; although factory installed insulation would be the best buy (if it is available), it is still worth retrofitting as long as long as the tank is relatively young. This study is further reviewed in Chapter III.

Eric Hearst and Janet Carney found that by adding $42 onto the initial cost of an electric water heater for insulation could save $36 annually at 1970 price levels; similarly, $40 added cost for gas water heaters would save $13 per year (12) (11).

Mutch considered solar water heaters in his study and found that the right system can be viable in every region of the United States. In the southern region (32^{o} N. latitude - below San Diego, Dallas and Atlanta) he found that a system which will provide 84 percent efficiency of a 50 gallons/day capacity tank having a lifetime of 10 years and an initial cost of a little over $500 with a discount rate of 8 percent, would be economically justifiable as long as electricity is at least 2.0¢/KWH. It is not justifiable for current gas or oil prices (1974).

A study by Richard S. Quinn dealt with the insulation of exposed tubing between the water heater and point-of-use. It was determined by using a hot water temperature of 140^{o}F produced an average ambient temperature of 65^{o}F with a 25 foot run. This could be justified only in areas where fuel prices are exceptionally high (18, p.).

Other possible methods of reducing fuel consumption are by turning the hot water temperature down or by using a timer to turn the heater off during long periods (daily) of non-use. These and other methods are discussed more fully in Chapters III and IV.

Appliances

Increasing appliance efficiencies, particularly refrigerators and stoves, would do much toward effective utilization of energy.

A Harvard researcher found that life-cost differences in some appliances are worth shopping around for. In one comparison, there was a $67 difference in the initial cost of two similar refrigerators. At prevailing electrical rates (1973 or '74), the cheaper model costs $746 to operate over a 20 year period while the higher priced unit cost only $392. Thus the more expensive model would actually be $287 cheaper, given a 20 year life expectancy (5, p. 140). As rates continue to climb the savings would continually increase.

If it were assumed that the fuel to power home refrigerators was produced from coal-fired plants, consumer purchase of more efficient refrigerators would mean the equivalent of 6 projected 1-million KW plants would not have to be built. Seventeen million tons of coal would be saved - would mean the atmosphere would be spared 690,000 tons of sulfur dioxide, 25,000 tons of particulates, 147,500 tons of nitrogen oxides, and thermal pollution. Additionally, 26,000 acres might be saved from strip mining, and another 10,000 acres on which the plants and transmission facilities would have been built, would be available for other use (5, pp. 190-91).

It has been found that energy consumed by refrigerators can be reduced by one-third with $10 added to the initial cost. The change would involve added insulation in the walls, increasing the condenser surface area, adding an anti-sweat heater switch, and moving the fan motor away from the refrigerated area; annual savings in electricity bills would be $20 - a 6 month pay-back period (12, p. 15).

A heat recovery system for refrigeration units was designed for a commercial supermarket chain. The entire space heating requirement was met with a 33 percent overall savings in energy consumption (27, p. 44).

Hittman Associates, conducted a study for the Department of Housing and Urban Development (HUD), found that by redesigning oven components and using different insulation materials, energy costs could be cut in half. They also found that energy could be saved through modified design of refrigerators and freezers so that waste heat could be used to supplement the water heating systems in the home. Although calculations showed an approximate $4 annual savings (at 1974 price levels), the added initial investment of $50 might make this option too high for consumers (10, p. 190).

Lifestyle plays a determining role in how much energy is used in the residential sector. Color television, frost-free refrigerators, and self-cleaning stoves all use more energy than previous models. The temperature maintained within a residence is also a major factor in how much fuel will be consumed.

A study comparing televisions sold in the United States in 1970 indicates that if all color television buyers had purchased the most efficient model, electric power consumption would have been reduced by one billion KWH; the approximate equivalent of one billion pounds of coal in the plant. Similarly, if all consumers buying black and white TV's had chosen the most efficient model, three-hundred million KWH's would have been saved, reducing the need for coal by 259 million pounds. Further savings would have been in terms of 'external' social costs, such as less lives lost to black lung disease (5, p. 191). Thus, economic and environmental advantages are clearly pointed out in even these relatively low-energy residential appliances.

Building With the Environment

Vitruvius, an ancient architect, was known to have given many specific suggestions for the citing and orientation of buildings and cities with regard to the sun, wind, and local climatic factors (5,p. 573).

In the past, civilizations minimized the dependence on outside sources of energy through the construction of homes and buildings designed for the prevailing climate. This art has been lost in the United States as homes and buildings in different parts of the country cannot be differentiated. This turnabout wrought by the development of a high energy society substituting the convenience of machines and brute-force energy for thinking and design. In general, buildings today are designed and constructed with excess ventilation, inadequate ventilation, and often with more window space than necessary. The result is excessive amounts of energy used for heating and cooling (5, p. 182).

Phillip Steadman's Energy, Environment, and Building (3) discusses environmental, good sense, and natural ways of conserving energy. Considerations include the orientation of a new house, fenestration, dome houses which reduce external surface area, underground housing, shading (by using deciduous trees, awnings, and other methods), and other natural means. Also, aside from several chcpaters on alternate energy sources, there is a section on autonomous, energy-conserving, ecological buildings and projects. Those who wish to do further reading in energy conservation are referred to the excellent bibliography given by Steadman (bibliographies given by Steadman on all subjects covered are pretty comprehensive).

A three page summary on the virtues of low-energy societies such as rural or urban communes is included in Wilson Clark's Energy for Survival (5). A much-to-valid point is made of the utterly total dependence with which today's 'modern' homes(and complexes) rely on outside energy for cooling due to their anti-climate - construction and orientation which preclude any possibility of natural ventilation.

Victor and Aladar Olygyay developed a comprehensive manual, under contract t o the government, as an architectural guide to natural design (5, p. 577-578). Four climatic regions are considered, Minneapolis, New York, Phoenix, and Miami - with specific recommendations for each area.

In the temperate New York area, the 'balanced' house of 1225 square feet was rectangular and maximized the interception of solar energy by utilizing large south-facing windows (double-glass) with overhanging roof to restrict admittance of the same energy during summer months. Good insulation, among otherthings, was also built in the mitigate climatic effects. End results, by laboratory tests, showed that the balanced house reduced winter heat loss by 49 percent over a conventional house of the same size. During the summer, by use of shading, improved ventilation techniques, shape, and arrangement of the house - energy use showed a 71 percent advantage over the conventional house (5, pp. 577-578).

Electricity and Gas

The scarcity and rising costs of energy have caused new considerations to arise when designing modern systems and structures. It is necessary to evaluate alternate sources of energy for both economic reasons and in the interest of long-term fuel supply (1, p. 632). There are many factors relating to the cost effectiveness of electricity compared to gas for residential energy purposes - with regard to heating-cooling systems.

When efficiency has been evaluated over an extended period of time and all losses considered, the overall efficiency of electric resistance heating is approximately 30 percent while fossil fuel heating is found to be about 40 percent for the average dwelling unit for the lifespan of a heating system (1) (30).

This tends to indicate that fossil fuel heating is somewhat more efficient than electric resistance heating, actual tests and empircal studies indicate little significant difference in the amount of raw energy used between the two when used for heating and cooling. In fact, one study revealed that electric heating and cooling used only 67 percent as much raw energy as required for fossil fuel heating and cooling - and only 87 percent as much required for fossil fuel heating and electric cooling. A similar study showed 86 percent and 107 percent, respectively, for the same comparison in homes instead of apartments (1, p. 632).

In contrast, a study conducted by HUD in the Baltimore/Washington area indicate that homes using natural gas for major heating, cooking and clothes-drying uses about half the energy it would require if they were total electric (5, p. 187). Major savings were in the central heating system - two-thirds annual energy savings was achieved here while gas clothes dryer, cooking range and water heater used about half the energy of their electrically operated counter-parts (5, p.187). It is assumed by this writer that the electrical heating systems compared were of the resistance type.

Two sicentists, A Makhjani and A. J. Lichtenber, of the College of Engineering at the University of California did a study of middle-class homes. Converting energy use in four sample homes to KWH (thermal) they accounted for fossil fuel energy content at the power plant with regard to electrical power used in the homes.

Energy use in the four homes varied from 58,000 KWH for thermal energy in a home heated with natural gas or oil (and with electric refrigerator and washer), to 112,620 KWH (thermal) in an all-electric home with electric appliances, air-conditioner, and stove. This was true even though the electric home had the most insulation (5, p. 189).

Human Awareness and Other Ways of Reducing Fuel Consumption

According to Fred S. Dubin, an authority on energy and energy conservation, improved maintenance practices in new and existing buildings in the United States could save more than 15 percent in energy consumption. In a home, one would schedule regular clearning or replacement of filters, check for leaky taps (and radiators), and regular inspections on weather seals around windows and doors (27, pp. 27 and 48). This could provide a possible 15 percent reduction in fuel consumption.

A study in Twin Rivers, New Jersey, by Grot and Socolow shows the importance of personal habits of the occupants within a home with respect to energy conservation. Identical developer-built houses with the same orientation, sitting side by side, and occupied by families of similar size and income, had as much as a 50 percent difference in the amount of gas used for heating. A tentative explanation had to do with personal habits, particularly as to the amount of time the windows and doors were kept open (27, p. 31).

One investigation by Dubin was to determine why two identical schools in Connecticut would have energy consumptions that varied from each other by as much as 100 percent; both were equipped with total electric heating, cooling and ventilation systems. Causes were found to be unnecessarily high thermostat settings, unnecessary light consumption, dirty filters, and continuous inactivation of the outside damper control (27, p. 48).

Among other ways of cutting down on energy consumption, it has been suggested that the use of heat exchangers to utilize the 'heat or cool' from conditioned air before it is exhausted from a building by transferring it to the incoming supply. This could reduce energy consumption by 30-35 percent in the winter and 15-20 percent in the summer. It is recommended that these devices should be considered in buildings where the ventilation rate exceeds 2000 cubic feet/minute (27, p. 54).

In 1975, it was estimated that pilot lights in American, gas-heated homes consumed 223 billion cubic feet of gas annually while several other means of ignition were and are available (27, p. 45). What is not pointed out in this instance is that the added heat from the pilot lights is energy that the heating system does not have to provide and the effect is just the opposite during warmer times.

Another possible method of reducing energy consumption is by the transfer of heat from lighting in the winter and rejecting it during the summer. There are several ways of doing this using air and water cooling, but it should be considered viable only when lighting levels exceed 75 footcandles, thus almost ruling it out for housing (27, p. 42).

In general, lighting levels are higher than necessary in residential housing. Cutting down where appropriate, and considering fluorescent lighting could save energy and money. A 40-watt fluorescent lamp provides more light than a 100-watt incandescent bulb at less than half the energy cost. They are considered ideal for the kitchen, garage, laundry, and work areas. Additionally, a fluorescent lamp has an expected lift of ten times that of an incandescent lamp.

During the summer, light colored roof and siding can make a marked difference in solar heat-up; also, an attic exhaust fan can be a worthwhile investment to keep the heat build-up down.

Mobile-homes accounted for one-fourth of all new housing in the United States in 1973. It has been observed that their construction requires high energy-intensive materials which consume great amounts of energy for heating and cooling in use. The roofs, walls, and window frames are commonly made of aluminum, just as are their structural supports. Aside from the high amount of energy required to manufacture aluminum, heat loss is twice as fast as through wood. They have been said to be, "the most energy-guzzling structures in the world!" (5, p. 186).

See Appendix B for other ways of saving energy in the residential sector.

Summary

It has been estimated (1975) that the typical family spends 5 percent of its annual budget on electricity, gas and gasoline. Because this is so low compared to other expenditures, efficient energy use has not been given much concern by the consumer (22, p. 487). This is changing with the escalating prices of energy.

In influencing energy conservation, changes in energy prices will influence initial investment as compared to life-operation-costs. Therefore, energy-conserving apparatus will be more economically justifiable. Public education would increase individual energy awareness and make people more sensitive to personal energy consumption. Government policies would greatly influence the efficiency of energy use in every area, being a determining factor in public education as well as the cost of energy.

Energy conservation is playing an increasingly important role in man's lifestyle. With the potential savings possible in the residential sector, it is imperative to consider the most effective and economically feasible means of saving energy in homes. Since most of the savings will be due to structural considerations, much that which applies to homes will also apply to commercial buildings.

By the year 2000, the use of energy in homes is expected to account for almost 24 percent of total United States energy consumption. Space heating and cooling, water heating, refrigeration, and cooking account for 85 percent of residential energy use.

Losses in the home are variously estimated from something over 30 percent to as much as 56 percent of total input - 79 percent of which is lost to the environment and said to be highly controllable.

The home's single largest energy user, space heating, had accounted for 11 percent of total United States consumption in 1970. Space heating is also where the most loss occurs (79 percent), thus, it is the area of largest potential savings. The ways of reducing energy used for heating are through improved building design (improved insulation and reduced infiltration), and more effective operations such as keeping the thermostat turned lower in the winter and properly maintaining the heating system.

The cost of heating a building can be expressed:

Seasonal Heating Costs ($/yr) =

Fuel Cost + Capitol Cost + Maintenance Cost

This assumes the maintenance of a constant temperature level.

Air conditioning is a particularly important consideration in reducing energy used because it is a major contributor to the peak loads many utility companies experience in the summer. Most of the improvements which reduce heating costs will also reduce cooling costs.

Windows account for 10-20 percent of building losses and can be half of heat loss or gain through walls. These losses can be greatly reduced by the addition of storm windows (or by using double or even triple pane windows), or by using a metallic glazing system.

Water heaters use 13-15 percent of residential energy or 3 percent of the total United States consumption and are another source of potential savings. Other possible means for improving efficiency are through added insulation, reducing the maintained temperature, using timers for automatic cut-off during period of non-use, and by supplementing with solar hot water systems.

A major way to save large amounts of energy is by building with the environment-taking advantage of all the nat ural heating and cooling methods possible. Existing homes can utilize such things as deciduous trees and proper shading techniques.

It is a subject of debate whether gas or electric homes use more raw fuel. There are studies supporting both sides of this issue.

There are many methods of reducing fuel consumption, such as maintaining the heating and cooling systems and turning them off during periods of non-use. Among other ways of possibly reducing consumption under proper conditions are by use of heat exchangers, the use of fluorescent instead of incandescent lamps (and not over-lamping), using light colored roofs and walls in warmer climates to reduce heat absorption, and closing blinds - at night to reduce heat loss or during the day to reduce the amount of heat radiated in.

Escalating energy prices are causing greater consumer concern in how to cut down on fuel costs. Changes in energy cost, public education, and governmental policies would go far in influencing the conservation of energy.

CHAPTER III

THE INVESTIGATION

Introduction

The purpose of this investigation was to identify several methods of energy conservation and determine the economic feasibility of these methods in the residential sector of southeast Georgia. The methods are restricted to those sectors utilizing proven technology.

A review of the residential sector shows that there are five major areas of energy consumption. Listed in descending order of energy use, they are: (1) space heating; (2) water heating; (3) space cooling; (4) lighting and all appliances other than for cooking, water heating, and clothes drying; (5) other devices not included in the list above.

This study will attempt to identify cost-effective energy conservation measures in the areas of water heating and space conditioning due to their large potential energy savings. Primary considerations are potential energy savings, initial expenditure, and payback period for each measure dealt with.

Localizing the Investigation-Water Heaters

In order to localize this investigation, it was necessary to obtain facts concerning the price of energy and the average temperature of cold water used for domestic purposes.

The cost of energy was obtained by telephone calls to the Georgia Power Company and gas companies in Statesboro, Georgia. Their prices were used to represent costs in southeast Georgia. The 1978 price of electricity from Georgia Power was averaged to be 3.59¢ per KWH for any amount over 650 KWH and using a weighted average for summer and winter months. The price of electricity from REA averaged to be 2.65¢ per KWH for any amount over 500 KWH. For purposes of this study, the price of electricity was assumed to be 3.8¢ per KWH. This was obtained by taking Georgia Power's rate and adding .21¢ per KWH to help offset fuel adjustment costs. The price of liquified petroleum gas (LPG) was found to be 50.9¢ per gallon and 38.4¢ per gallon. It was decided to average these prices for this study, yielding 44.7¢ per gallon. The heat content of LPG ranges from 90,000 to 105,000 Btu per gallon.

In an interview with Ed Cone, Statesboro's City Engineer, it was found that the price of natural gas in that area is generally about one third cheaper than LPG (6).

The average cold water temperature is very close to the average temperature of local rivers, which are close to the average temperature in a given geographic region (14). The temperature used for purposes of this study was derived by adding the average temperatures given by the National Climatic Center for Macon, Augusta, and Savannah (64.6°F, 64.6°F, and 66.8°F, respectively) over a 40 year period from 1937 to 1976. The mean figure and the figure used in this study was 65°F.

The data for solar water heaters in this area was obtained from C. M. Mobley (16). The cost of an installed system was approximately $1500. The system is anticipated to have a 20 year life time and capable of supplying 90 percent of the hot water needs for a family of four at 140°F. The system is representative of those available in southeast

Georgia.

The Sea Island Bank of Statesboro was contacted about the cost of a $1500 loan for a solar system. If the loan is paid back over a five year period, the payments would be $429.12 per year so that the total payback sum would be $2145.60.

Conservation Measures for Water Heaters

With a hot water system (usually a hot water tank in which the water is heated by electricity or gas), the amount of energy required depends on the temperature at which the hot water is maintained, the number of gallons of water maintained at that temperature, the ambient temperature of the cold water used, the efficiency of the heating system (gas, electric, solar), the amount of hot water used, the insulation and the distance that the tank is located from the point of use.

During the course of the investigation, several energy conservation measures were decided worthy of closer examination. The primary measures considered are:

1. Reduction of maintained water temperature
2. Reduction of the amount of water used
3. Use of solar energy for pre-heating and for supplying all hot water possible
4. Increasing insulation
5. Use of timers for automatic switching

The economics of tank insulation and the use of timers for automatic switching are compared in Residential Water Heating: Fuel Conservation, Economics, and Public Policy. Findings concerning the addition of insulation are as shown in Table 10, p. 55. The results assume a hot water temperature of 140°F, an ambient temperature of the air around the tank of 70°F, and an expected lifetime of 10 years. Factory installed insulation is assumed to be two inches for electric water heaters and one inch for gas and fuel-oil units. For more details see reference (18).

When considering a timer to control the electric current, a hot water temperature of 110°F was assumed. Shutdown would be from 12:00 midnight to 6:00 a.m., and the timer cost would be approximately $10. Electricity would have to cost $4.50/therm (15¢ per KWH) and gas or fuel oil would have to be at least 90¢ per therm before a timer would be economical. Before prices got to this point, the economics of thicker insulation would outweigh that of timers, thus making timers uneconomical even at higher prices due to less savings (once the insulation was installed)(18).

Another study (15) assumes a hot water temperature of 140°F, an ambient temperature of 80°F, electricity cost of 4¢ per KWH, an installed timer cost of $50, and an 'off' period of 18 hours per day. Assuming a clock lifetime of 10 years, a savings investment ratio of 2.62, and a discounted annual savings of $141, it was found that the payback period for the timer would be two years and ten months for a four person dwelling. The writer observed that timers can sometimes be purchased for $20.

For the analysis of energy for hot water heating, the basic expression used in this study was:

$$KWH = \frac{(T_{hot} - T_{cold})\ (2.45 \times 10^{-3})\ (H_{total})\ (N)\ (D)}{Efficiency} \qquad (28)$$

TABLE 10*

RESIDENTIAL WATER HEATER TANK INSULATION: MINIMUM-COST THICKNESS,[a] ECONOMIC BENEFIT, AND ENERGY BENEFIT WITH PRESENT RANGE OF ENERGY PRICES

Item	Factory-Installed Insulation			Retrofitted Insulation		
	50-Gallon Electric					
Electricity price (¢/kWh)	1	2	4	1	2	4
Minimum-cost insulation	4"	5"	7"	2"	2"	6"
Annual cost saving	$1.40	$4.00	$10.10	--	--	$4.90
Annual electricity saving (percent)	8.1	9.5	11.0	--	--	10.4
	40-Gallon Natural Gas/LPG					
Natural gas price (¢/therm)	10	20	40	10	20	40
Minimum-cost insulation	3"	4"	5"	1"	3"	4"
Annual cost saving	$2.90	$7.90	$15.50	--	$2.50	$10.70
Annual gas saving (percent)	21.6	23.8	25.0	--	21.6	23.8
	40-Gallon Fuel Oil					
Fuel oil price (¢/gallon)	20	30	40	20	30	40
Minimum-cost insulation	4"	4"	5"	3"	3"	4"
Annual cost saving	$4.80	$7.90	$11.20	$0.70	$3.50	$6.60
Annual oil saving (percent)	23.8	23.8	25.0	21.6	21.6	23.8

*Residential Water Heating: Fuel Conservation, Economics, and Public Policy

[a]Based on 10-year lifetime and an inflation-free, after-tax discount rate of 8 percent.

Where: KWH is the number of kilowatt hours used.

T_{hot} is the maintained hot water temperature .

T_{cold} is the temperature of incoming water to the system (65^{o} for purposes of this study).

2.45×10^{-3} is a constant derived by dividing the number of Btu's required to raise the temperature of one gallon of water $1^{o}F$ (8.3453) by the number of Btu's KWH (3413).

H_{total} is the number of gallons of hot water used/person/ day.

N is the number of people within the residence.

Efficiency is the efficiency of the type water heater being considered.

Nominal end use efficiencies for electric, gas, and oil water heaters are 100 percent, 70 percent, and 67 percent, respectively (18, p. 8). The calculations in this study will concern themselves only with electric units.

D is the number of days over which it is wished to calculate energy use.

The factors that an individual may change in this expression in an effort to reduce power consumption are T_{hot}, T_{cold}, or the number of gallons used.

As the temperature is reduced, more hot water is needed to satisfy household uses due to less cold water being mixed to achieve the final temperature. In considering this factor, the expression used to determine how much hot water is needed is as follows:

$$H_{final} \text{ (gallons)} = \frac{T_n(U_{hot} - T_{cold})}{T_{hot} - T_{cold}} \qquad (19)$$

Where: H_{final} is the amount of hot water needed from the tank

T_n is the total number of gallons needed (Hot + Cold) for a particular use

U_{hot} is the final temperature of the water needed

T_{cold} is the temperature of the cold water coming into a system (65^{o} for purposes of this study)

T_{hot} is the temperature of the water in the tank

This equation must be considered for each new temperature when using the equation (28) to determine the energy (KWH) needed.

The minimum requirement for water temperature known at the date of the study which is specified by dishwasher manufacturers is 140^{o}F. This temperature is to insure efficient operation and because several dishwashing powders need this temperature to dissolve properly (15, p.9). If there is a booster heating element in the dishwasher, or if there is no dishwasher, the thermostat can be turned down to around 120^{o}F if hot water is needed for laundry. If 100^{o}F water is used for bathing, water over about 100^{o}F has to be mixed with cold water in order to reach a comfortable bathing temperature. If there is more than one water heater in the house, the only unit that might be turned to a high temperature is the one providing water for the dishwasher or laundry. If the water heater is of the quick recovery type, there are two heating elements and frequently two thermostats. The upper thermostat should be adjusted to the water temperature desired to maintain while the lower thermostat should be set about 10^{o}F lower (15, p. 6).

The amount of hot water needed per day was determined (28, 27, 1, 18) as shown in Chapter IV, Table 13 p. 66 . It was calculated that 20 gallons per day per person of hot water were used when the maintained temperature is 140°F. All references indicated this as a guide.

Where energy cost increases are considered, a factor of 8 percent was used. This figure was taken from a 1977 study for Georgia Power Company by M. L. Berg on energy formulas dealing with utility savings in the residential sector (2, p. 9).

Localizing the Investigation - Space Conditioning

Localizing the investigation for this section of the study involved the gathering of information for the southeast Georgia area concerning: energy prices; the number of cooling and heating degree days; prices for various materials including insulation, storm windows, heat pumps, and air conditioning (AC) with resistance heating; the expected lifetime and cost of the compressor for heat pumps and air conditioning; representative coefficient of performance (COP) and energy efficiency ratings for both systems.

The cost of energy was the same as for those explained previously for water heaters, 3.8¢ per KWH for electricity and 44.7¢ per gallon for LPG.

The number of heating degree days used for this study is 2,271. This figure was derived by averaging the number of heating degree days given by the National Climatic Center for Augusta, Macon, and Savannah over a 21 year period (1956-1977). The number of cooling degree days, 2,162, was derived in a similar fashion over an eight year period.

The information concerning heat pumps and AC/resistive heating was obtained from H. A. Sack, Inc. in Statesboro (9) - the facts gathered were summarized in Table 11.

TABLE 11

FACTS ON HEAT PUMPS AND AC/RESISTANCE HEATING USED IN THIS STUDY

	Size	Initial Cost	COP	EER	Compressor Cost	Expected Lifetime
Central AC with	2 ton	$1300	-	8.5	$450	7 yrs.
Resistance Heating	4 ton	2600	-	8.5	650	-
Heat Pumps)	2 ton	1650	2.25	8.5	450	5 yrs.
)	4 ton	3300	2.25	8.5	650	5 yrs.

Table 11 is representative of numbers said to be typical and average for this area.

The prices of insulation and storm windows were checked with vendors in Statesboro. The price of a self-installed fiberglass batt in Statesboro was $150 per 1000 square f-ot for 3½ inch batt (R-11) and $250/1000 square feet for six inch batt (R-19). There is a difference in the price of storm windows, the lower two prices averaged together yielded $1.87 per square foot and was used where applicable in this study; the same method was used to get the price for storm doors, the final figure is $3.21/square foot.

Interest rates for savings accounts were obtained from a Statesboro bank (23). The rate used was 7.79 percent annually. This rate could be obtained with a $1000 minimum if put in the six year non-withdrawal plan.

Conservation Measures for Space Conditioning

The energy conservation measures chosen for investigation in this study have a positive affect for both space heating and cooling, both heating and cooling seasons will necessarily be considered when deciding on the value of any measure. The feasibility of the methods depends on whether or not they are economically beneficial to the consumer.

Considerations in this area of energy conservation were:

1. Air conditioning/resistance heating compared to the heat pump
2. Attic insulation
3. Storm windows
4. Storm doors

For purposes of this study it is assumed that homes in southeast Georgia are heated 150 days/year and cooled 150 days/year, leaving 65 days during which neither air conditioning or heating are needed.

The expression used for the analysis of dollars saved per area are affected by modifications was:

$$\$ \text{ Saved} = (T_{diff}) (\Delta U) (A) (3.6 \times 10^{-2}) (C) \qquad (27)$$

Where: T_{diff} is the difference in temperature between sides of the area being considered

ΔU is the change in U values for the area being considered

A is the area being considered in square feet

3.6×10^{-2} is the number of hours per heating or air conditioning season (24 x 150) divided by 100,000 Btu's (1 therm)

C is the cost of energy/therm for the particular system being considered.

The T_{diff} depends on the area being considered (ceiling or window) and season. It was assumed that during the heating season, the maintained indoor temperature was 68°F and the average attic temperature was 55°F ($\Delta T = 13^{o}F$). During the cooling season, the indoor temperature was assumed to be 78°F, and the average attic temperature was assumed to be 90°F, ($\Delta T = 12^{o}F$). For windows, and doors, ΔT during the heating season is 18°F, (68°F-60°F); ΔT during the cooling season is (1°F-78°F).

In doing an economic assessment the following expression will yield the accumulated fuel savings for a given year:

$$\text{Accumulated Fuel Savings} = \frac{1-(1 + r)^{n}}{1-(1 + r)} \quad S \qquad (1)$$

Where: r is the annual energy cost increase

n is the number of years being considered

S is the first year savings

The amount of money paid on the loan (or the system) up to the point being considered can be subtracted from the accumulated fuel savings (from equation 3), yielding the net savings.

Summary

The methods of energy conservation considered were in the areas of water heating and space conditioning. Primary considerations are the potential energy savings, initial expenditure, and payback period for the measures considered.

The prices of electricity and LPG were obtained from the Georgia Power Company and from local gas companies and their prices were used to represent the southeast Georgia area.

All information having to do with weather conditions were obtained through the National Climatic Center's information folders on Macon, Augusta, and Savannah. The data for these cities was averaged together and used to represent southeast Georgia. Information included the number of cooling and heating degree days with the average temperature.

The conservation measures considered for water heaters included the reduction of hot water temperature, reducing the amount of hot water used, the use of a solar water heating system, increasing the tank insulation, and the use of timers to turn the unit off during long periods of non-use. However, both the use of timers and the addition of insulation were summerized in this chapter.

The basic expression for energy use in the production of hot water was:

$$KWH = \frac{(T_{hot} - T_{cold})\ (2.45 \times 10^{-3})(H_{total})\ (N)\ (D)}{Efficiency}$$

As the temperature of the maintained hot water is reduced, more hot water from the tank is needed to satisfy demands; the following expresses that relationship:

$$H_{final}(gallons) = \frac{T_n(U_{hot} - T_{cold})}{(T_{hot} - T_{cold})}$$

Information to localize the study for space conditioning involved consideration of energy prices (the same as for water heaters), the number of heating and cooling degree days, various facts on heat pumps and AC/resistance heating systems, the cost of storm windows and insulation, and the interest rate for savings accounts.

The methods to be investigated for space conditioning are AC/

resistance heating compared with the heat pump, attic insulation, and storm windows.

The basic equation used to calculate savings for increasing the R-factor over a given area was:

$$\$ \text{ Saved} = (T_{diff})\ (\Delta U)\ (A)\ (3.6 \times 10^{-2})\ (C)$$

The expression for accumulated savings was:

$$\text{Accumulated Savings} = S\left(\frac{1-(1 + r)^{n}}{1-(1 + r)}\right)$$

This expression with other information can be used to determine net savings for a given year.

CHAPTER IV

ANALYSIS OF DATA

Introduction

To determine whether certain energy conservation measures (outlined in Chapter III) are cost-effective in southeast Georgia, the primary considerations are the effectiveness and the payback period of a given method.

Residential Water Heaters

Reduction of Hot Water Temperature

It has been determined that energy can be saved by reducing the hot water temperature. This is particularly appealing because there is no investment other than a few minutes of time, and savings begin immediately.

A consideration in determining overall savings when the temperature is reduced might be how much more hot water will actually be needed. Equation two yields the results given in Table 12, p. 65, when values for T_{hot}, U_{hot}, and T_n are those indicated by the table, and T_{cold}, is 65^oF.

From Table 12, p. 65, the amount of hot water needed increases as the temperature is reduced. The relationship is not linear.

With the (H_{final}) figures from this table and using equation (28), it is possible to calculate the approximate possible savings each year for reductions in hot water temperature.

TABLE 12

TYPICAL DAILY HOT WATER USAGE/PERSON AT VARIOUS TEMPERATURES

Use	U_{hot}	T_n-Gals.	150°F	140°F	130°F	120°F	110°F	100°F
Bathing	100°F	25	10.3 gal.	11.7 gal.	13.5 gal.	15.9 gal.	19.4 gal.	25
Washing (Dishes & Clothes)	T_{hot}	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Kitchen	100°F	5.4	5.4	2.2	2.9	3.4	4.2	5.4
Miscellaneous	T_{hot}	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	Total(H_{final})		18.3	20	22.2	25.1	29.4	36.2
	KWH/Day		3.81	3.68	3.54	3.38	3.24	3.10

For a family of four using unheated or cold water with a temperature of 65^oF, the following data are shown in Table 13:

TABLE 13

POTENTIAL SAVINGS BY REDUCING THE HOT WATER TEMPERATURE

Water Temp.	No.Gals/Day For 4 People	KWH/Day	KWH/Yr.	Cost/Yr.*
150	73.2	15.2	5564	$211
140	80	14.7	5366	204
130	88.8	14.1	5162	196
120	100.4	13.5	4938	188
110	117.6	13.0	4732	180
100	144.8	12.4	4532	172

*An Electrical Rate of $0.038/KWH is assumed.

For a family of four, the potential savings average to be around $8 per year for every 10^oF the thermostat is reduced, this breaks down to be about $0.17 per person/month. The savings would be marginally greater than this due to reduced heat losses through the tank as the ambient temperature and the hot water temperature get closer togehter. This method for calculating savings is written in Mutch's study (18).

These same savings would be achieved if the cold water temperature were raised as with solar power, heat exchangers, or some other means. If this calculation is carried through, first using equation (19), T_{cold} is the numerator, the temperature would still remain 65^o, or the ambient cold water temperature, it is T_{cold} in the denominator that would change. If all incoming cold water could be raised 10^o, the annual savings would be about $49 annually, (however, this might not be desirable or possible without an oversized preheating system which would make the cost economically unfeasible).

Reducing the Amount of Hot Water Used

Another method for reducing the amount of energy needed for hot water which requires no investment is by reducing the amount of hot water used.

Using Equation One it was found that in one year that if a gallon of hot water could be saved every day, the savings, with a hot water temperature of $140^{o}F$, would be $2.55. If everyone in a family of four would conserve one gallon, the savings would be $10.20 annually or a 5 percent reduction in fuel cost to the consumer. This savings goes down by about .5 to .6 percent for each $10^{o}F$ lower than the thermostat is set.

The amount of hot water used may be further reduced by taking showerd instead of baths, using a restricted-flow shower-head, washing clothes in cold water, or being aware of how much hot water is being used and reducing the amount used. Letting a faucet flow needlessly or permitting a leak to continue will increase the amount of energy needed to maintain a supply of hot water.

A pipe loss problem was done to determine how much hot water is lost when the tank is located some distance away from the point-of-use. It was assumed that the water pipe averaged one-half inches in diameter and the run was 75 feet from the water heater to the point of use and that the water in this line would be lost completely on the average of twice a day.

The equation used was:

$$\text{Volume of } H_2O = (75') \, (\pi) \, (1/48')^{2} (7.48)\text{gal/ft}^{3}) \, (2 \text{ times/day})$$

Results were that if the 75 foot run could be completely eliminated, 1.53 gallons less hot water would be used daily; an annual savings of \$3.90 if the maintained hot water temperature is 140°F. This may not be feasible in all homes.

Solar Energy for Water Heating

The system outlined in Chapter 3 would provide 90 percent of the hot water and needs for a family of four; using this system, the savings would be \$183.60 on the \$204. normally spent for electric water heating.

The economics for a solar hot water system is shown in Table 14, p. 69. The costs shown is if a five year loan is assumed and an 8 percent annual energy cost increase. As can be observed in the Net Savings Column, the investment will pay for itself in the 8th year. After 10th, 15th, and 20th years, the net profits will be \$514, \$2,839, and \$6,256, respectively. If a 10 percent inflation rate is assumed this money will have a present worth of \$200, \$681, and \$930, respectively.

At the end of 20 years, a new system would need to be installed and it is assumed that similar savings should occur along the same pattern as for the replaced equipment.

Space Conditioning

The Heat Pump and Air Conditioning/Resistance Heating

In considering the economics of heat pumps compared with AC/ resistance heating, it is convenient to use the cost per therm. The operating cost for a heat pump with a coefficient of performance (COP) of 2.25 (for heating) is found to be 49.5¢ per therm and resistance heat

TABLE 14

ECONOMICS FOR SOLAR WATER HEATING SYSTEM

Year	Annuel Savings*	Accumulated Fuel Savings	Debt	Annuel Payment	Net Savings/ Year	Net Savings
0	0	0	$2145.60	0	0	0
1	$183.60	$183.60	1716.48	$429.12	$245.52	$-245.52
2	198.29	381.89	1287.36	429.12	-230.83	-476.35
3	214.15	596.04	858.24	429.12	-214.97	-691.32
4	231.28	827.32	429.12	429.12	-197.84	-889.16
5	249.78	1077.10	0	429.12	-179.34	-1068.50
6	269.77	1346.87	-	0	+269.77	-798.73
7	291.35	1638.22	-	-	291.35	-507.38
8	314.66	1952.88	-	-	314.66	-192.72
9	339.83	2292.71	-	-	339.83	147.11
10	367.02	2659.73	-	-	367.02	514.13
11	396.38	3056.11	-	-	396.38	910.51
12	428.09	3484.20	-	-	428.09	1338.60
13	462.34	3946.54	-	-	462.34	1800.94
14	499.32	4445.86	-	-	499.32	2300.28
15	539.27	4985.13	-	-	539.27	2839.55
16	582.41	5567.54	-	-	582.41	3421.96
17	629.00	6196.54	-	-	629.00	4050.96
18	679.32	6875.86	-	-	679.32	4730.28
19	733.67	7609.53	-	-	733.67	5463.95
20	792.36	8401.89	-	-	792.36	6256.31

*An 8 percent annual rate increase is assumed.

shall be considered 100 percent efficient, making the price $1.11 per therm. The cost of cooling is the same for both systems assuming an energy efficienty ratio (EER) of 8.5. This cost is 44.7¢ per therm.

From a survey used for an unpublished study, it is found that 12,000,000 Btu's per month (120 therms per month) in a representative house in Statesboro is typical for the amount of energy used for heating during the winter months. This means that a four ton unit would be used; the initial outlay, taken from Table 11, p. 59, is $3300 for a four ton heat pump and $2600 for an AC/resistance heating system of the same size. The compressor for an air conditioner has an estimated life expectancy of seven years while the heat pump compressor has a life expectancy of five years .

Collected data indicates that the heat pump will cost $297 per season to operate while the resistance heater will cost $666 per season. Since cooling costs are the same for both units, they were not considered. There is no loss-of-interest taken into account on the extra $700 initial heat pump investment due to the fact that within two seasons the total resistance heating cost over-takes that of the heat pump. After seven seasons the heat pump has a total cost of $6029 including the replaced compressor for $650. The resistance heating system had a cost of $7262 before installation of a compressor and $7912 after the AC compressor has been replaced. After the first two seasons, the heat pump has made up for the higher initial outlay - even after the fifth year when the heat pump compressor is replaced, the resistance heater has a higher cost than the heat pump by nearly $500. If the rising cost of energy was considered, the savings would be even greater - however, there is no doubt as to the better buy.

If the heat pump systems were two ton units and energy usage was scaled down, results would be the same percentages but actual dollar savings would be less.

Attic Insulation

The addition of attic insulation to an optimum point is considered to be one of the most effective ways of reducing energy costs. The Georgia Power Company recommends a factor of R-30 in the ceiling for this area. Many people wonder if it is really worth the money for extra insulation if they already have some insulation overhead.

The problem considered here is whether it is good economics to add six inches of fiberglass batt (R-19) overhead to a home that already has an overhead insulating factor of R-11. An R-factor of 1.71 is typical for a ceiling if there is not any overhead insulation (14) - this factor will be taken into account when doing the problem.

There are 2271 heating degree days during an average year - divided over the heating season, the average is approximately 15 degree days for each of the 150 day season. The National Climatic Center uses $65^{o}F$ as the base temperature in their calculations, meaning that all days with average temperature under $65^{o}F$ are considered as so many cooling degree days. Taking this into account it is found that the average temperature during the heating season is $50^{o}F$. An average attic temperature of $55^{o}F$ is assumed and the inside temperature used is $68^{o}F$. Equation three used as follows:

$$\$ \text{ Saved} = (68^{o}-55^{o}F)\left(\frac{1}{12.71} - \frac{1}{31.71}\right)(1000 \text{ sq.ft.})(3.6 \times 10^{-2})(\$1.11)$$

The result is a \$24.49 savings during one heating season for every 1000 square foot insulated when resistance heating is used.

During the cooling season there are 2162 degree days - averaging 14.41 degree days for the 150 day season (14.41 x 150 = 2161.5). Again a base temperature of $65^{o}F$ is used. Thus, the average temperature is calculated to be $79^{o}F$ inside temperature is assumed to be $78^{o}F$. The attic temperature is assumed to be a nominal $90^{o}F$. Equation three yields a savings of \$9.10 during the cooling season. Thus total savings per 1000 square foot for one year are \$33.60 using an AC/resistance heating system. The simple payback period is about seven years five months. If an 8 percent annual energy increase was assumed, the payback period would be reduced to just under six years and one month. This does not take inflation or a loss in interest on the original $250 into account. If a heat pump is used, the savings during the heating season fall off to $10.92 - a total yearly savings (summer costs + winter costs) of $20.00 per 1000 square foot. This stretches the simple payback-period to right around 12½ years.

Assuming an 8 percent annual energy increase, it would take approximately nine years to recover the initial investment cost.

Storm Windows

Since windows can easily account for more than 10 percent of the losses from a home, or one-half of the losses through a wall, they are an important consideration. A single pane window has a U-value of 1.13, a storm window will reduce this value to .54 - a reduction of more than 50 percent (3)(21). This is more of an increase in thermal resistance than double-pane windows give until their dead air space exceeds one-half inch.

The price for storm windows used in this investigation is $1.87 per square foot. Using equation three, savings during the heating season using heat pumps or resistance heating are 19¢ per square foot and 42.4¢ per square foot, respectively. During the summer months, the saving due to the added storm windows are practically negligible at 95¢ per square foot.

With a heat pump, this means a simple payback period of nine years and ten months; with resistance heating the break-even point is faster with the simple payback period being only four years and five months. In this case the investment can be concluded as being worthwhile. Actual savings by the addition of storm windows are greater than indicated due to reduced air infiltration which is not accounted for here.

Storm Doors

Thermal losses through doors are less than through windows for the typical residence. The U-factor for a wooden door with a nominal thickness of one inch (actual thickness of 25/32") is generally around .69. A storm door increases the resistance such that a U-value of .35 can be achieved (21). The storm door must have a good fit and not be loose or it can be disregarded as having real insulation properties.

The price used for storm doors in this investigation is $67.41 per door, or $3.21 per square foot. Using equation three, savings during the heating season when using a heat pump would be 11¢ per square foot; if resistance heating is used, the savings are 24¢ per square foot. Savings during the cooling season are 0.6¢ per square foot. This means a simple payback period of 27.67 years when heat pumps are used or 13.05 years if resistance heating is used. If electric rates increase at 8 percent per year, payback periods would be 15.16 years and 9.28 years, respectively.

Summary

The first technique considered in reducing the amount of fuel needed for the production of hot water was simply lowering the temperature of the maintained hot water temperature. An important consideration was the fact that more hot water will be used as the temperature is reduced. The potential savings by this method is approximately $8 per year assuming four people in the residence use an average of 20 gallons each per day per person.

Making the same assumption (80 gallons of hot water used daily), the fuel cost for water heaters can be cut 5 percent if each person could use one gallon less of hot water each day. A situation was considered concerning losses in the hot water line between the water heater and the point-of-use; the savings were not significant when all factors are considered.

By using a solar water heater, large amounts of energy can be saved. The particular system used in this example would pay for itself in the eighth year, at the end of the fifteenth year, the net savings would be $2839.55, a present-worth value of $681 if a 10 percent inflation rate is assumed.

The economics comparing the heat pump with the AC/resistance heating unit indicated the heat pump to be a better buy. In a typical residence, the simple payback of a heat pump making up its added initial cost (over that of an AC/resistance heating system) would take only two seasons. The seasonal cost of operating a heat pump was found to be $297 as opposed to $666 for resistance heating.

Adding enough insulation overhead to increase from a factor of R-11 to R-30 will pay for itself (simple payback) in a period of seven years and five months if an AC/resistance heating system is used. When a heat pump is used, the simple payback period is extended to 12½ years.

Storm windows can reduce window losses in half (in addition to reducing infiltration losses). The simple payback period for this investment is nine years and ten months if a heat pump is used or four years and five months if a resistance heating system is used.

Storm doors have the longest payback period of any energy conservation method considered. Simple payback would take 27.67 years and 13.05 years for a heat pump and an AC/resistance system, respectively. If an 8 percent annual electricity rate increase was assumed, the payback time would be reduced to 15.16 years with a heat pump, and 9.28 years when AC/resistance heating is used.

CHAPTER V

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The hypothesis for this study was: Modifications can be made to homes in the southeast Georgia area resulting in less energy consumption and a direct dollar savings to the consumer within a reasonable time.

Data which would have impact on the southeast Georgia area was gathered in the Statesboro area or from the National Climatic Center. These considerations included heating/cooling systems, weather, interest rates, and prices on any insulation materials.

Findings

Energy conservation measures were studied for space conditioning and water heating systems which would be suitable for southeast Georgia.

There are several options which the consumer can consider in reducing fuel consumption for heating water. Turning down the hot water temperature is an economical method because there is no initial investment. For a family of four, the savings average $8 per year for every 10^{o}F lower that the thermostat is adjusted. As energy prices rise, this savings will increase proportionately.

Another method to reduce required energy is by using less hot water. It was found that if one gallon of hot water could be saved each day, an annual savings of $2.55, or $10.20 for a family of four, would result if the maintained hot water temperature was $140^{\circ}F$. This is a 5 percent overall savings for hot water.

The solar water heating system evaluated in this investigation could supply 90 percent of the hot water needs for a family of four, at a temperature of $140^{\circ}F$. The life expectance of this system is 20 years and the initial investment would be $1500. The annual savings with this system would be $183.60 of the $204 normally spent for fuel. Assuming an 8 percent annual electricity rate increase and a five year loan with annual payments of $429.12 (a total cost of $2145.60), the system would pay for itself in the eighth year. After 10, 15, and 20 years, the net profits would be $514, $2,839, and $6,256, respectively. If a 10 percent inflation rate is assumed, this money would have a present worth value of $200, $681, and $930.

An important consideration in space conditioning is a comparison of heat pumps with air conditioning/resistance heating systems with similar output capabilities. The initial cost of an installed heat pump system is approximately $3300 as opposed to $2600 for an AC/resistance heating system; the operational costs per heating season are $297 and $666, respectively. The compressor cost for each four ton system considered is $650; expected lifetime is five years for the heat pump compressor and seven years for the AC/resistance compressor.

Analysis shows that the heat pump would offset its higher initial cost within two years. From this time on, the heat pump continues to improve its economic lead over the AC/resistance heating system. At the end of seven years, after compressors for both systems may have been replaced. Total heat pump costs are $6,029, and total AC/resistance heating costs are $7,912 or a savings of $1,883. If a 10 percent annual inflation rate were assumed, the present worth of this savings would be $960.

The use of storm windows can reduce losses through single-pane windows by more than 50 percent. Using local-area prices, the simple payback period is nine years and ten months if a heat pump is used, or four years and five months if AC/resistance heating is used. It was determined that the use of storm windows and storm doors during the cooling season is practically negligible.

Similar to windows, the value of storm doors can reduce losses by almost half; however, storm doors are a more expensive investment. It was found that where resistance heating is used, the simple payback period would be 13.05 years, if a heat pump is used, the payback period would be 27.67 years. With an 8 percent annual electrical rate increase, the payback periods would be reduced to 9.28 years and 15.16 years. Storm doors have the slowest return of any option considered.

Conclusions

There are several cost-effective measures which can be used to reduce energy consumption in southeast Georgia, therefore, the Hypothesis for this study was accepted.

The methods for energy conservation with the highest rate of return are those requiring no financial investment, such as reducing the hot water temperature or using less hot water.

Storm windows will pay for themselves faster than will overhead insulation if the change in insulation considered is increasing from R-11 to R-30. Storm windows also have a greater energy savings per square foot. However, total dollar-savings over a period of several years will depend on the total window area as compared to total ceiling area.

The solar water heater is also a cost-effective means of reducing energy consumption. Due to the relatively large initial investment, it takes several years to pay off, however, once the initial cost is recovered, the savings accumulate fast.

The single best method of reducing energy expenditure will vary depending on the individual house and the habits of the occupants.

Recommendations

The government should become more involved with residential energy conservation. Minimum Property Standards (MPS) on government financed housing should be increased to the economic optimum where conservation techniques are concerned. The optimum point would vary according to the part of the country in which the house is located.

Through government programs, the consumer should be made aware of the cost-effective energy conservation techniques available. Also, a very important step the government should take is to make conservation techniques more cost-effective to the consumer through incentives such as tax-breaks for proven methods implemented by the individual.

Private enterprise should initiate accurate consumer directed programs which keep the public informed as to proper practices for economy.

It is recommended that the consumer institute the measures applicable to his home that deem themselves cost-effective on the basis of information presented in this study, not only for economic reasons but in order to conserve the vital energy sources that are being depleted so rapidly.

Anyone building a new home should build with the environment, using shading, natural ventilation, orientation of the house, fenestration, and other techniques.

Summary

It was found that there are several cost-effective options available to the consumer in the southeast Georgia area that can save on energy consumption.

Two methods, requiring no investment, that reduce fuel consumption are reducing the hot water temperature and the amount of hot water used.

The use of solar water heating was found to be cost-effective and has the possibility of substantial savings. Due to the relatively high initial cost, the payback period takes several years. However, the initial investment is recovered, savings increase rapidly.

Heat pumps were compared to AC/resistance heating and were found to be the better investment. Though the initial investment for the heat pump is greater, operational costs make up for this within two heating seasons.

The addition of overhead insulation is beneficial. If the additional insulation is used to increase the rating from a factor of R-11 to R-30, the simple payback period is seven years and five months if AC/resistance heating is used, or 12½ years if a heat pump is used.

Storm windows effectively reduce heat losses through single-pane windoes by more than fifty percent. Simple payback is under ten years if a heat pump is used and less than 4½ years with an AC/resistance heating system. Storm doors also reduce losses by almost half; however, the higher cost of storm doors makes them the least cost-effective conservation measure considered.

The government should take a more influential position in the conservation of energy in the residential sector, in particular, it should increase Minimum Property Standards where energy conservation is concerned, have stronger programs to educate the public on methods of energy conservation, and give incentive to the consumer to institute energy conservation methods.

The single best method of reducing energy cost will vary depending on the individual house and the habits of the occupants.

All natural techniques possible be employed to cut down on energy consumption.

APPENDIX A

RESIDENTIAL ENERGY USAGE-
TYPICAL APPLIANCES

RESIDENTIAL ENERGY USE-TYPICAL APPLIANCES*

Appliance Assuming Normal Use→	Electric Pwr. & Energy Use			Gas Energy Use	
	Average Power (WATTS)	Typical Use (KWH/Yr.	Typical Use (GJE/Yr.)	Typical Use (Kft^3/Yr.)	Typical Use (GJ/Yr.)(b)
Air Conditioner (window)	1,325	1,320	4.7		
Air Conditioning (central)	3,000	3,600	13		
Bed Covering (automatic)	190	132	0.5		
Broiler	1,560	96	0.3		
Clock	2	24	0.09		
Clothes Dryer (Electric)	4,350	840	3.0		
Clothes Dryer (Gas)				5	5.3
Coffee Maker (automatic)	850	96	0.3		
Deep Fat Fryer	1,440	96	0.3		
Dishwasher	1,180	348	1.3		
Fan (attic)	365	324	1.2		
Fan (circulating)	85	48	0.2		
Fan (window)	200	170	0.6		
Food Blender	290	12	0.04		
Food Freezer (standard, 15 ft^3)	350	1,056	3.8		
Food Freezer (frostless,15 ft^3)	440	1,524	5.5		
Food Waste Disposer	400	24	0.09		
Frying Pan (automatic)	1,160	192	0.7		
Furnace (Gas burning)				65	69
Gas Light (outside)				18	19
Grill (sandwich)	1,180	36	0.13		
Hair Dryer	260	12	0.04		
Heat Lamp (infrared)	250	12	0.04		
Heater (portable)	1,200	1,200	4.3		
Iron (hand)	1,085	144	0.5		
Iron (mangle)	1,500	156	0.6		
Lamp (one)	100	150	0.5		

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RESIDENTIAL ENERGY USAGE-TYPICAL APPLIANCES (Continued)

Appliance Assuming Normal Use→	Electric Pwr. & Energy Use			Gas Energy Use	
	Average Power (WATTS)	Typical Use (KWH/Yr.)	Typical Use (GJE/Yr.)	Typical Use (Kft^3/Yr.)	Typical Use (GJ/Yr.)(b)
Lights (household)	1,000	2,000	7.2		
Microwave Oven**	900	162	0.58		
Pool Pump Motor (3/4 h.p.)	1,100	4,000	14.4		
Pool Pump Motor (1 h.p.)	1,400	5,100	18.4		
Pool Heater (Gas burning)				50-150	53-158
Radio	75	84	0.3		
Radio-Phonograph	115	108	0.4		
Range (Electric)	12,000	1,200	4.3		
Range (Gas)				10	11
Refrigerator (standard, 12 ft^3)	265	852	3.1		
Refrigerator (frostless, 12 ft^3)	295	948	3.4		
Refrigerator-Freezer (standard, 14 ft^3)	290	1,200	4.3		
Refrigerator-Freezer (frostless, 14 ft^3)	435	1,572	5.7		
Roaster	1,325	204	0.7		
Sun Lamp	280	15	0.05		
Television (black and white)	255	360	1.3		
Television (color)	315	456	1.6		
Toaster	1,130	36	0.13		
Vacuum Cleaner	700	36	0.13		
Waffle Iron	1,080	20	0.07		
Washing Machine (automatic)	600	84	0.3		

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RESIDENTIAL ENERGY USAGE-TYPICAL APPLIANCES (Continued)

	Electric Pwr. & Enginer Use			Gas Energy Use	
Appliance Assuming Normal Use→	Average Power (WATTS)	Typical Use (KWH/Yr.)	Typical Use (GJE/Yr.)	Typical Use (Kft^3/Yr.)	Typical Use (GJ/Yr.)[(b)]
Washing Machine (non-automatic)	280	60	0.2		
Water Heater (Electric)	4,500	3,876	13.9		
Water Heater (Gas)				30	32

*Efficient Electricity Use
**1978 Manufacturers Specifications.

APPENDIX B

DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS

DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS*

Reduce Use of Equipment	Reduce Losses	Substitutions for Same Function	Maintenance and Prevention	Reduce Connected Load and Other
(Space Heating or Cooling)				
Turn heater thermostat to 20°C (68°F) in day, to 15°C (60°F) at night, (4% day, 6% night)	Install and use shades, drapes, awnings, louvres, on south, west (2%)	Use ventilating fans where appropriate, particularly for kitchens or laundry (1%)	Keep filters cleaned regularly (<1%)	Shut off unused rooms and spaces (3%)
Set A/C thermostat to 26°C (78°F) (15% fuel)	Keep leaking down around windows, doors, fire-place (3%)			
Run A/C only on really hot days (2%)	Use storm windows or tack on clear plastic sheet (3%)			
Modify clothing to ac-commodate to wider comfort limits (2%)	Where glass area is large add a second pane (3%)			
Use opendable windows to cool (3%)	Use light color drapes facing outward (<1%)			
Reduce attic ventila-tion in winter (1%)	Use shrubs, vines outside as shades for sunlight (2%)			
Maintain a constant thermostat setting (<1%)	Insulate floor of attic (1%)			
	Shut off pilot lights in summer when away (1%)			

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DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS (Continued)

Reduce Use of Equipment	Reduce Losses	Substitutions for Same Function	Maintenance and Prevention	Reduce Connected Load and Other
		(Refrigeration Freezing)		
Pre-cool heated foods prior to loading in refrigerator/freezer (2%)	Reduce door openings to nimimum (5%)		Keep rear coils (heat exchanger) clean (<1%)	Check actual need for the use of your second refrigerator (8%)
Remove no more ice cubes than needed (<1%)	Be sure refrigerator is not against hot walls, so insert a sheet of fiberboard and an extra air space (2%)		Make sure door gaskets close tightly all around, replace if torn (1%)	
Empty refrigerator, leave off and open for vacation (2%)			Make sure interior lamp extinguishes when door closes (push door switch with finger) (2%)	
Set thermostat to keep food at 4-5^{o}C (39-41^{o}F) (ref.) or -17^{o}C to 12^{o}C (0-10^{o}F) (3%) (freezer)				

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DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS (Continued)

Reduce Use of Equipment	Reduce Losses	Substitutions for Same Function	Maintenance and Prevention	Reduce Connected Load and Other
		(Water Heater)		
Set thermostat to 49°C (120°F)(10%)	Water heater is located in a cold cubicle add fiber sheet or other insulation (2%)	Wash clothes in cold water with cold-water soap (4% fuel)	Check flame adjustment annually, if gas (1%)	
Don't wash dishes under running hot water; run dishwasher only when fully loaded, or wash by hand (3%)	Check leaky hot water faucets (& pipes)(1%)	Use lower flow shower heads (5%)	Add pipe insulation, if convenient (3%)	
			Check and repair heater insulation (1%)	
		(Lighting)		
Turn off lights when not used(signs: "last out-lights out")(15%)	Where possible, use fluorescent lamps in place of incandescent (40 W vs 100 W)(15%)	Use sunlight at periphery of house (2%)	Replace fluorescent tubes as soon as they begin "blinking" (<1%)	In clusters, remove one bulb permanently (3%)
Concentrate light in reading and work areas; cut general room lighting (5%)	Use one large bulb in place of several small ones (e.g., 100W vs. 2-60 W) (1%)	Light colored walls and ceilings, reflective screens reduce the need for artificial lighting (2%)	Keep lamps and fixtures clean (<1%)	Remove lamps used for decorative purposes only (3%)
			Reconnect large areas so as to be served by more than one switch(2%)	
Remember heat from lights adds to the A/C load (1%)	Turn off outside night lamps during day (<1%)			

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DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS (Continued)

Reduce Use of Equipment	Reduce Losses	Substitutions for Same Function	Maintenance and Prevention	Reduce Connected Load and Other
(Cooking and Related Appliances)				
Use all-oven-cooked meals (3%)	Cover the pans; use pans that cover the heating element(<1%)	Use hand mixing, etc., where appropriate(<1%)	Keep pans flat bottomed for electric heating units (<1%)	Plan use of heavy load appliances before 8 a.m. or after 6 p.m. when possible (e.g., vacuum clean or iron up a batch on week-ends)
Use oven self-cleaning option sparingly (2%)	Permit the cooking appliance to heat the kitchen, as a consequence of its use; vent the range in the summer to reduce A/C load (1%)		Keep range exhaust filter clean(<1%)	
Plug in counter-top roasting appliances only as long as cooking (<1%)	Do not pre-heat oven more than 2-3 minutes (<1%)		Check whether a defective appliance is at end of useful life (<1%)	
Turn down heat when pot bubbles (<1%)	Do not use range to heat the house (<1%)		If gas, check setting for blue-flame; adjust pilots (<1%)	
Turn off heater several minutes before food is done (1%)	Pre-scrape dishes to permit use of short cycle (<1%)			
Use a single small appliance (e.g.,Casserole cooker) in place of a larger device(2%)				

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DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS (Continued)

Reduce Use of Equipment	Reduce Losses	Substitutions for Same Function	Maintenance and Prevention	Reduce Connected Load and Other
		(Laundry and Dishwasher)		
Use washers with full loads of mixed sizes of articles($3/bill)	Match detergent to the water hardness, save rinses(<1%)	Dry clothes on rack or outdoors, when suitable (2%)	Keep water and air filters cleaned out (<1%)	Run machines at off-peak times, such as before 8 a.m. and after 6 p.m.
Where available use "suds-saver"(1%)	Open dishwasher door for air drying after last rinse (1%)	Hand wash single items (<1%)		
Use dryer only with load that has gone through a full spin-out cycle of washer (2%)	Use only the number of cycle portions necessary (e.g., skip soak cycles)(<1%)			
Set dryer times for proper time and temperature (2%)	Avoid over drying (<1%)			
Partially dry clothes, fold and place on dryer during next load(2%)				

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DIGEST OF HOUSEHOLD OPERATIONAL OPTIONS (Continued)

Reduce Use of Equipment	Reduce Losses	Substitutions for Same Function	Maintenance and Prevention	Reduce Connected Load and Other
		(Tv, Radio and Other Appliances)		
Keep sets off except when actually attended (1%)	Unplug "instant-on" TV sets when not in use (3%)	Use small screen TV sets where possible (1%)	Keep cutting edges sharp for motorized tools (<1%)	
Watch swimming pool pump and heater for unnecessary use (1%)	Check percolator, electric blankets, and heating pads when not in use (1%)	Develop other forms of family home entertainment(2%)		

Notes: ( ) indicates: savings
<1% means less than 1%

*<u>Efficient Electricity Use</u>

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