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TO DETERMINE THE FEASIBILITY OF SOLAR ENERGY FOR HOME HEATING SYSTEMS

Edward Harris Blackmon

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TO DETERMINE THE FEASIBILITY OF SOLAR ENERGY FOR HOME HEATING SYSTEMS

by

Edward Harris Blackmon

A thesis submitted to the Faculty of
Georgia Southern College in partial
Fulfillment of the requirement for
the Degree of Master of Technology

Statesboro, Georgia

August 2, 1974

Approved by

Committee:

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Department Chairman

Dean, Graduate School

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CHAPTER I

INTRODUCTION

Background and The Reasons for the Study

The years 1973 and 1974 will go down in history as the years of eht energy crisis. Our modern civilization is completely dependant on cheap and abundant energy. The economic wealth and material standards of living of a country are determined by the technologies and fuels which are available. Our fossil fuels: coal, fuel oil, gasoline, and natural gas, give ample heat and power at extraordinary low prices, and they are constantly releasing more men from manual labor and making them available for operating power driven machines. Every year our dependance upon energy becomes greater and greater. Suburban developments require more automobile transportation, and greater electrification is occuring in industries and homes. As a consequence, we expect that in the future there will be a limited supply of fossil fuels (9, p. 1).

At this time man has begun to seek other sources of energy. One considered is nuclear energy; but nuclear energy must come in large, expensive units, and it will find its greatest use in Northern climates where large quanities of energy are needed in cities and manufacturing areas. Another possibility is solar energy which comes in small, safe units in sunny, rural regions. Solar heating systems operate on very basic principles. They are simple and safe because of the low operating temperatures. They can be installed in small systems and maintained by unskilled home owners.

Both nuclear and solar energy are free from the serious handicap of the high transportation cost which greatly affects the fossil fuels. Among all the uses of solar energy residential heating has the highest possibility of success according to a study completed by the National Science Foundation and National Aeronatics and Space Administration Solar Energy Panel (27, p. 28).

The direct use of sunlight to supply the basic human needs for energy is of primary importance to man's continual survival on Earth, where the stored fuels, fossil or organic, are being consumed at an incredible rate. Only green plants are able to directly convert the sun's energy into fuel and food for animal needs. But the amounts thus produced, large as they are, can not keep pace with the requirements after the stored supplies of fossil fuels have been consumed (8, p. xiii).

Table I lists the known sources of energy. (Department of Agricultural Engineering, University of Georgia, 1973).

TABLE I

KNOWN SOURCES OF ENERGY

Source of Energy	In Giga Watts
Annual USA Requirement, 1972 rate of use	1,000
Annual World Requirement, 1980 rate of use	10,000
Electric Generating Capacity, USA	300
Electric Generating Capacity, World	1,000
Coal, World's Ultimate Supply	1,700,000
Oil, World's Ultimate Supply	330,000
Natural Gas, World's Ultimate Supply	100,000
Annual Wind Energy	30
Annual Tidal Energy	100
Annual Solar Energy	50,000,000
Liquid Metal Fast Breeder Nuclear (Annual Nuclear Energy by 1990)	4,200,000,000
Fusion Reactor, Deuterium from Oceans (Annual Nuclear Energy possibly 2000)	10^{14}

*Giga Watt = 10^9 Watts

*1 KWH = 10,000 BTU

The units are in giga-watts, which is ten to the ninth power. It is important to note that solar energy is more abundant as an energy supply than coal, oil, or natural gas all combined. Therefore, the development of solar energy

for use in home heating should be considered to help conserve our fossil fuels. With such a large potential of energy supply which has yet been untapped--it would be truly a mistake if man ignores such a potential source of energy. A large number of factories, schools and other industrial buildings have a large roof area which is available for solar collectors. This area now is not fully utilized--it is limited to duct work, vents, and a few air conditioning units. The potential for installing solar collectors on these rooftops and utilizing them to supply heat for the building below is evident.

The Problem of Study

To determine the feasibility of implementating solar powered house and hot water heating systems for Georgia home owners is the problem of study.

Hypothesis

Solar energy has the potential to immediately supplement home heating systems and solar hot water heating systems for Georgia home owners.

Basic Assumption

The assumption fundamental for this research was that the units of heat required for heating the house or the water is independant of the method for generating it. There are a definate number of British Thermal Units required to heat any particular house.

Definition of Terms

Several terms used in this research are listed alphabetically and defined as follows:

Auxiliary Equipment is the necessary pipe, controls, heat exchanger, heat transfer fluid, valves, pump motor, etc. to couple all the necessary equipment into the system.

Baseboard Heaters are units recessed in or mounted on the baseboard of the outside walls of a room. Heating elements, inside the baseboard sections, cause a rising flow of warm air. The cold air enters a slot in the bottom and leaves through a slot near, or at, the top of the unit. Glass panel (radiant) baseboard heaters are available. Overheating cutout switches operate if air flow is restricted.

Furnishings should not be placed directly against baseboard units. These units are difficult to locate in some rooms, such as the kitchen and laundry. They are not suitable where full length draperies are to be used. (26, p. 3).

The blower is a fan used to move the air through the collectors and heat storage bin (21, p. 7).

BTU refers to British Thermal Unit which is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit (26, p. S-7).

A heat storage system refers to material which has a high specific heat or experiences a change of phase and which accepts collected solar heat as available and allows

it to be withdrawn as needed (16, p. 2). Figures I and II are examples of two types of heat storage systems.

Instantaneous peak is the maximum demand at the instant of greatest load, usually determined from the readings of indicated or graphic meters (26, p. S-11).

Kilowatt refers to the unit for measuring electrical power. One kilowatt is equal to 1,000 watts. One kilowatt equals to 3,413 BTUs per hour (26, p. S-11).

Kilowatt-Hour is the unit for measuring electrical energy. One kilowatt-hour is equal to 3,413 BTUs. (26, p. S-11).

"R factor" indicates the heat flow resistance of the insulation. The higher the number, the greater the efficiency of the insulation. R factors should fall in these ranges: ceilings, R - 13; walls, R - 11; and floors over unheated space, R - 9-11 (19, p. 84).

A solar collector is a surface or composite surface which by virtue of geometry or surface properties absorbs solar energy and imparts this energy to a heat-transfer fluid which circulates through the collector (16, p. 2)

The wall heater unit has a space behind the radiant heating element and reflector. The air in this space is heated and rises from the top of the unit which, at the same time, is radiating additional heat into the room. The heater is mounted on the outside wall between the studs. Open space is necessary in front of the heaters.

FIGURE I

LIQUID HEAT STORAGE UNIT

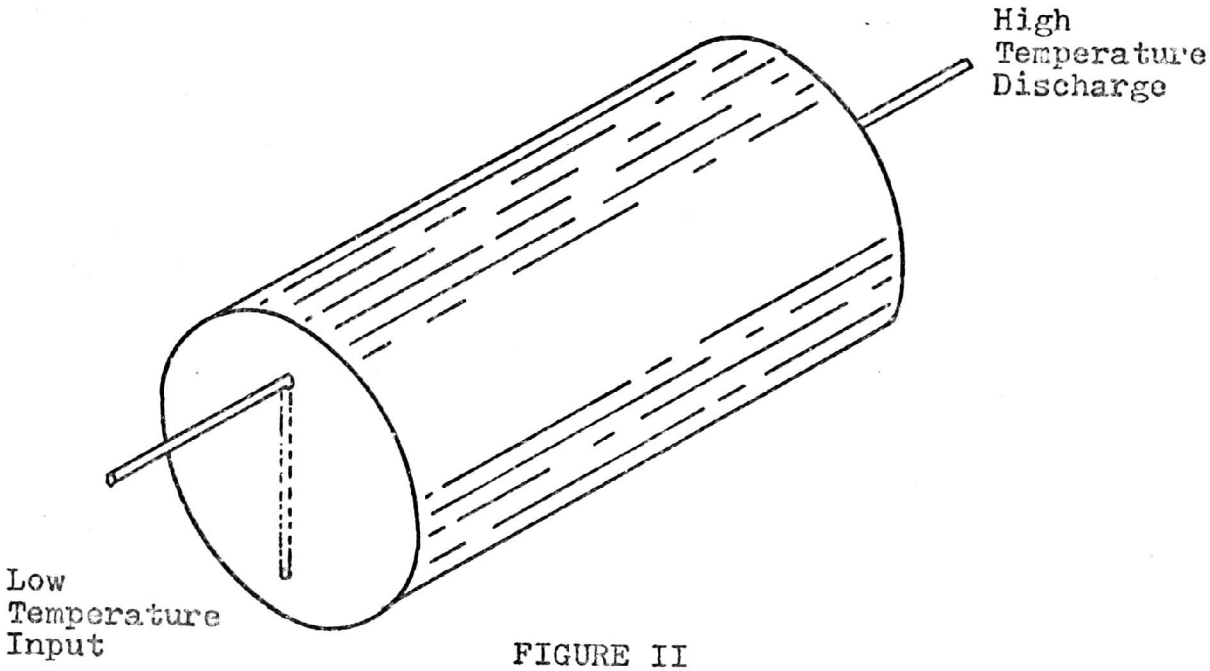
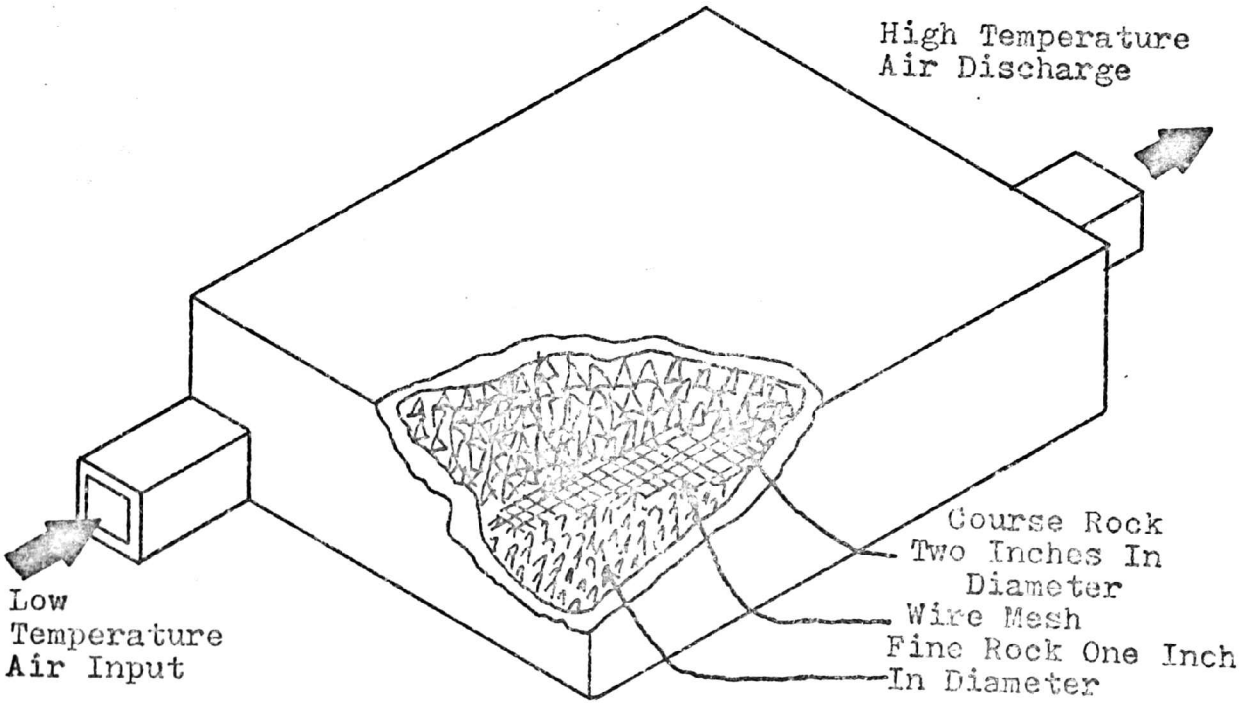


FIGURE II

HOT AIR HEAT STORAGE UNIT



Wall draperies cannot be used in front of them (26, p. 5).

Water heater refers to an apparatus for heating and usually storing hot water. The commonly-used immersion type of hot water heater (standard) is metal sheathed resistance wire packed in magnesium oxide. Since the unit is located in the water, practically all the heat is transferred directly to the water. The quick-recovery electric water heater is virtually two heaters in one. The top quarter of the tank can be considered one heater; the lower three-quarters as another (26, p. 5).

Limitations and Controls

The study was based on a house with a thousand square feet (heated space), and a heating requirement of 28,826 BTUs per hour (Table II, page 9), and a hot water system with a forty-gallon capacity rated 40,000 BTUs per hour heating requirement. The house had three-inches of insulation in the walls, four-inches in the attic, and two-inches in the floor. Standard, single pane glass was found throughout and forced air central heating (heat pump). The hot water heater was heated by electricity. The solar collectors and heat storage unit were attached to the system utilizing existing air ducts and blower. The solar panels when constructed should face south, elevated at an angle of thirty-one to thirty-five degrees above the horizon. This system will supplement the existing system and will not be used as a primary system.

TABLE II

SPECIFICATION DATA ON HOUSES FOR DESIGNING

ELECTRICAL HEATING SYSTEMS

(Johnson Builders' Supply)

(Washington, Georgia)

House Number	Heated Area (Square Feet)	BTUs per Hour	Glass Area (Square Feet)
1	1196	36,481	202
2	1146	27,324	215
3	1698	38,201	276
4	1354	53,568	240
Totals	5397	155,574	

House Number	INSULATION (inches)			Design Temperature
	Ceiling	Walls	Floor	
1	5	3	2	+10°F
2	6	3	3	+10°F
3	6	3	3	+10°F
4	6	4	4	+10°F

$$\text{Average BTU/hr.} = \frac{\text{Total BTUs}}{\text{Total Sq. Ft.}} = 28{,}826 \text{ BTUs/hr.}$$

Overview of the Study

The emphasis is placed on using the solar energy for heating as a supplementary means. There is a maximum dependance on the solar system, as a result only a small amount of electrical energy is necessary to heat the house and reduce the consumption of fossil fuels, especially during the time when energy is in short supply. The roof of the house may be used as part of the solar system for the collection of energy, which reduces wasted space.

Summary

Utilization of other sources of energy besides fossil fuels is imperative because of the exhaustion of these fuels. Solar energy is a logical source for house heating and hot water heating, especially in Georgia where the climate is conducive to the utilization of solar energy. The use of nuclear reactors is far in the future and man needs energy now. If solar energy is feasible for Georgians in house and hot water heating, then there is an abundant supply of energy from the sun.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Beginning in 212 B.C. when Archimedes aimed large metal mirrors to catch the sun and burn the sails of the Roman fleet at the Battle of Syracuse, man has continually attempted to harness the sun's power (11, p. 18). Almost all the research and development of solar heating has been directed toward medium and high-priced residences in areas where conventional fuel and electricity are plentiful and cheap. Since twenty per cent of the United States consumption of fuel is used for heating buildings (8, p. 107) it is evident that solar energy for heating could well provide the means for conserving the United States and World supply of coal, oil, or gas.

From a technical standpoint, solar house heating is easily accomplished, but from an economical and architectural standpoint there are difficulties. Combustible fuel in the United States and elsewhere was cheap so that it was difficult except in special cases to save enough fuel by using the sun to compensate the larger capital investment required for the solar heating system. In regions where most

heat is needed the sunlight is of lowest intensity in the winter. The heat collector is a major cost item, and the expense of equipment to provide enough storage capacity to carry a house or building through a week or more of cloudy weather in cold climates is more expensive than existing heating systems. For these reasons most advocates of solar heating now accept auxiliary heating by fuel as a necessity where long sessions of cloudy days or extremely cold spells are likely. All solar heated houses built and planned thus far, require auxiliary heating for the operation of the system.

As in many other uses of solar energy, the first economically sound application of house heating will probably come where sunlight is abundant and fuel is expensive. Very little research has been devoted to solar heating where electricity is not available. Solar house heating may also become important where both solar heating and solar cooling can be accomplished with the same equipment (8, p. 107).

Studies of a Similar Nature and Design

Pioneering work in solar house heating has been done at the Massachusetts Institute of Technology under the general direction of Prof. H. C. Hottell. A significate conference on solar space heating was held in Cambridge, Massachusetts, in 1950. Two successful and attractive solar houses have been designed and tested in Tokyo, Japan. They

include a solar heating and cooling with water and the use of a heat pump. The house has an unglazed solar collector of 1410 square feet with an area for domestic hot water on a nearly horizontal roof. The collector is made of expanded channels of blackened sheet aluminum. The hot water tank holds 9,600 gallons and weighs four tons. A three-horsepower motor operates the heat pump for auxilary heating and cooling (8, p. 113).

The largest house with solar heating is in Denver, Colorado. The house has 3,200 square feet. The solar collector has six hundred square feet of area and was made by overlapping glass plates inclined to the south at a forty-five degree angle on a horizontal roof. Heated air is stored in twelve tons of rock pieces one and one-half inches in diameter contained in two hundred fifty cubic feet of vertical concrete pipes in the center of the house. The normal maximum air temperature was 140 degrees Fahrenheit. The sun supplies twenty-six and five tenths per cent of the heating and natural gas supplies the rest (8, p. 113).

A solar heater laboratory has been built at Tucson, Arizona. The installation was completed in 1959 and the heating tests commenced in the winter of 1959-60. The building, styled as a bungalow, was used as a laboratory for solar energy research. It has 1600 square feet of floor area, well insulated and has 435 square feet of double windows. The heat requirement at the design temperature

of thirty degrees Fahrenheit was 34,600 BTUs per hour. The unique feature of the system was that it uses the solar collector not only as a heat receiver, but also as a heat radiator for cooling purposes. This 1600 square foot area covers the entire roof and actually serves as the roofing as well as a heat exchanger. It was constructed of copper sheet with 120 intricate panelled tubes, five-sixteenths of an inch in diameter and five inches apart, connected at their ends with hot and cold manifolds. The material for the collector surface was shipped flat in long coils, sixteen inches wide and the tubes were inflated hydraulically at the construction site. These pieces were joined together on the roof by means of cleats to form a continuous metal surface. No glazing was used on the metal plate and for asthetic reasons, a dark green paint was used rather than black.

The heat storage unit was a tank containing approximately 4500 gallons of water. This tank was divided into two sections by means of a horizontal insulating baffle so that water at two different temperatures can be stored simultaneously. Auxiliary heat was supplied to the building by means of a small heat pump running hot water from the solar collector or from the hot section of the storage tank. It can be used for supplying the heating requirements directly. At other times when it is not hot enough it serves as a low temperature heat supply to the heat pump; heat was delivered to the building from the high temperature side

of the heat pump. Heat was transferred to the rooms by use of a continuous, radiating ceiling constructed of the same material as that used on the roof. Water was circulated through sixty-six paralleled tubes in thirty-three circuits.

The heating panel completely covers the ceiling of all rooms having a total area of 1320 square feet. When operated as a cooler, water was pumped from the storage tank through the roof heat exchanger at night, radiating heat into the atmosphere. On a clear summer night a large area of the unglazed unit permits discharges up to one and one-half million BTUs from water at about seventy degrees Fahrenheit. On the following day the cooled water was used directly in the ceiling panels for building cooling or if its temperature was too high the heat pump chills it by transferring heat into the hotter condenser section of the storage tank. This heat was dissipated the following night in the roof heat exchanger. Thus, the heat pump was used as an auxiliary in all seasons supplying energy when water in storage was too hot or too cold to carry their respective loads.

The performance of this heating and cooling system was carefully analyzed through the latter half of 1959 and throughout 1960 and parts of 1961. Reliable operation was achieved with close control of temperature of seventy-five degrees Fahrenheit at all times. During 1960 thirty-five million BTUs were supplied for heating of which five million BTUs were from electrical sources. Thus about eighty-six

per cent of the energy for heating was solar (9, p. 278).

Another study on heating and cooling utilizing the electrical energies provided by the sun was done by the University of Delaware's Institute of Energy Conservation in Newark, Delaware. They introduced a house called Solar One. For the first time a system converts sunlight directly into both heat and electricity for a house and electricity for the power company. Although the house remains unoccupied for the time in order to accumodate the volume of visitors and to allow experiments to continue, the household functions such as lights, heat and air-conditioning, humidity, water and appliances are continually operated by computer to simulate normal usage. Ultimately the University plans to use the house as a guest house.

Like half of an A-frame house, the south facing roofline swoomps downward at a forty-five degree angle to provide exposure to the sun. The first floor consists of a living room, dining room, kitchen, two glass-walled bedrooms, one full and two half baths. Space for a family room or garage now houses a solar education display. The second floor of the A-frame house now contains experimental equipment which will be converted later into additional bedrooms. The full basement shelters the heat storage unit and instrumentation designed to record the day by day functioning of the equipment.

The roof encloses twenty-four panels, three of which

are made of cadmium-sulfide solar cells. The others contain a variety of heat-collecting materials employed on an experimental basis. Within the year, all twenty-four panels will contain solar cells. To warm the house, air forced through the solar collectors is heated by contacting the back of the hot solar cells as well as by passing over six additional black surface panels constructed in the south wall of the first floor. In the daytime duct work carries surface hot air to the basement storage unit which is composed of plastic tubes filled with a chemical salt. The salt melts at a temperature of 120 degrees Fahrenheit absorbing large amounts of heat from the hot air. At night when there is no sun to warm the air and the house cools, air circulates through the tubing and extracts heat from the salts. In this way solar energy can supply the needs over several cloudy days. During the summer this same process reverses for air conditioning. At night cool air freezes other salts at fifty degrees Fahrenheit, releasing the cooling as air passes over the salts during the day (11).

Another house was designed in Connecticut by two Yale faculty members. Architect Donald I. Watson and Engineer Everett M. Barber, Jr. who teach courses on energy conservation. There are no moving parts in the solar heating system in the Connecticut home. On the roof of the house are thirty-six collector modules. Each is about two feet wide arranged in three rows of panels six feet high. The collectors are

simple in design. A sheet of glass stretches over a copper plate coated with a selective black finish to maximize the absorption of sunlight and minimize radiation of heat from the black surface. A solution of ethelene-glycol anti-freeze is circulated through blackened copper pipes built into the collector surface and down into the basement of the house to heat an enormous 2000 gallon water tank. The tank is designed to store heat from the collectors at night and for as long as four to five days of cloudy weather. Mr. Barber's estimates that ideally the solar collecting panel should equal forty per cent of the heated space inside the house. More than two dozen houses have been constructed using this basic type of heating system (7).

One leading solar energy engineer Dr. George Löf of Denver, Colorado, has built two houses using solar heating. He is now constructing a third under a grant from the National Science Foundation (7).

Former attorney Harry Thomason of Washington, D. C., has constructed three solar houses in the Washington area. Mr. Thomason reported that during the first year of operation the heating system in his first house provided more than ninety per cent of the heating needs of the home, requiring the expenditure of only $4.64 for oil for a supplementary heater. The following winter, 1960-61, proved to be the coldest in Washington in forty-three years, yet the family spent only $6.30 for supplementary oil. Mr. Thomason, now

living in a spacious house equipped with a rooftop collector, reports continued satisfaction with solar heating technology.

Architect Donald Watson, co-designer of the Connecticut solar home, is convinced that more people would build such houses today if lower mortgage rates were made available for energy-conserving features. "Banks don't figure life-cycle costs in today's house loans", he says, adding that the additional initial costs of a solar-heating system would raise the tax assessment of a home (7).

Addressing this very problem, the state of Indiana recently acted to permit all residents to deduct the added value of solar heating and cooling systems from the assessed value of their real estate. In addition, Congressman Charles Vanik, Democrat of Ohio, introduced legislation in the Congress to grant a tax credit to homeowners of up to $1,500 for the installation of solar heating equipment and other energy-conserving features such as insulation and storm windows (7).

The use of solar energy for household heating is not a new technology, and stems more from the tradition of architecture than the history of engineering. Solar engineer Dr. Jerome Weingart, formerly of the California Institute of Technology, points out, "It's the most trivial kind of technology imaginable". In fact the use of solar collectors and heat-storage systems is more of a plumbing problem than an engineering problem (7).

The nation need not wait years for a scientific validation of solar energy for heating. What is needed is recognition by architects and builders that housing design can incorporate solar-energy technology as an integral part of the house (7).

An English translation of a Russian magazine which explores the possiblility of using solar collector water heat exchanger for showers in construction camps, summer cottages, and dwellings where water heaters with a large working surface was available. The solar water was collected from the solar heat collector which consists of a shallow pan with a black bottom and coils running back and forth approximately five centimeters on center. The bottom of the pan was flooded with water to cover the coils. To increase the conduction of heat an oil film was placed on top of the water. The entire collector was covered with glass. The black bottom of the solar water heater collector absorbed the solar energy. The oil film helped prevent evaporation of the water and the water helped to increase the efficiency of the solar heat collector coil. Glass was used to keep out foreign material and reduce the evaporation of the water. The water was then feed to a storage tank and from the storage tank, directly to shower heads in the shower rooms of the construction camp, summer cottage, or dwelling (2).

The required capacity of a hot water tank depended on

the amount of water consumed per day. If water was used often the capacity of the tank should be not less than the hourly consumption. It was also noted that in constructing the solar collector water heater, the roof tank must never be in the shade. The height of the tank does not matter, since it had no affect on the operation of the collector. The entire system is set up on gravity feed and no circulation pump is needed (2).

In summary, the article states that solar water heaters using solar coil water heat exchangers as described are the cheapest and simplest to build and operate as compared with other solar systems. In building dwellings with flat roofs, part of the roof was adequate to receive the solar collector water heater installation for supplying hot water (2).

Summary

The data support the conclusion that it is possible to achieve heating utilizing collector plates located on the roof preferably a flat roof of a building with a large storage tank and heat exchanger panels located in the rooms. The outlook for the use of solar energy for heating is very good.

CHAPTER III

THE CONTRIBUTION OF THE PRESENT STUDY

Introduction

This study was completed during a period when energy was at a premium. Many Gerogians were faced with a problem of trying to meet their budget demands with new high prices of fuel. Georgia has short winters with few low temperature days. The present study of information concerning solar energy and its application to home heating systems and hot water systems allows the house owner in Georgia to decide whether or not it is feasible to utilize solar energy to ease his heat bill during the winter months and furnish hot water for the house year round.

Availability of Data on Solar Energy

There are several books available with extremely detailed information about the uses of solar energy. One is The Direct Use of the Sun's Energy by Farrington Daniels and covers all aspects of solar energy from collectors to solar radiation in the United States, History of solar energy, solar furnaces, solar stoves (heat cookers), and methods of distilling water to name a few of the articles

using solar energy: 271 pages on solar energy.

Also the Arthur D. Little Co., Inc. has quite a bit of information concerning the availability of materials by American and foreign manufacturers, listing several manufacturers here in the United States and abroad who are selling items utilizing solar energy for home heating, cooling, hot water heating, swimming pool heaters, to name a few of the applications. This is a one good source if one is vitally interested in solar energy to purchase materials (preconstructed) from manufacturers.

Arthur D. Little has been engaged in a year long project to assess the market prospects and business opportunities of solar climate control. As of this date eighty-one major organizations around the world are supporting the project.

Edmund Scientific Corporation is another source of information. They have available house plans which were designed by Dr. Harry E. Thomason. They sell a set of house plans and a revised edition of his book Utilizing Air Conditioning, and also a license to build one of Dr. Thomason's houses.

Helio Associates, Inc. has a book called Solar Energy Warm House Heater - Build It Yourself. It utilized readily available materials and is designed to supplement heating systems for houses as well as mobile homes. This is important

in Georgia especially since we have a large number of areas populated by mobile home builders, because of the rapid growth of our cities. It is a simple straight-forward approach to help alleviate the high expense of heating houses or mobile homes.

Georgia Power Company is very cooperative in helping evaluate the electrical needs and furnish information concerning electrical types of heaters, hot water heaters, house heaters enabling one to get a comparison for his particular area or region.

Solar One is a study using sunlight for both heat generation and electrical generation for a house. This is a study that has been done by the University of Delaware and was of interest since it deals with the generation of electricity as well as heat by utilizing direct conversion of the sun's energy. Data may be obtained by writing the University of Delaware.

Portable water tanks which heat water with solar energy are available from Frank L. Suhay of Glendale, California (15). The unit can absorb enough solar energy to raise four gallons of water thirty degrees Fahrenheit in three to six hours.

It is made of foamed-polystyrene with an aluminum sheet heat exchanger surface having molded-in channels for water flow. Its greatest potential use is in giving portable hot water at no cost to families who go "car" camping.

Solar water heaters of 200 liter capacity for household

chores, including bathing, laundering, and cooking are available from Hitachi. The solar heat collecting cylinder is made of rigid polyethylene and is installed on the sunniest side of the roof and is most efficient when elevated at an angle equal to the latitude of the location. The heater was fixed on the roof with lag bolts and wires. The heater should be filled with water during the day to prevent overheating. During the winter, the water in the cylinder and pipe would be drained to prevent freezing.

A self-contained solar water heater designed to meet the requirements of a family of five is manufactured by Smalls Sola Heeta Co., Pty., Ltd. The heater has a forty gallon storage cylinder placed horizontally on a twenty-eight square foot solar absorber. The product is designed for easy installation by an amateur on any roof.

Procedures and Techniques of Solar Energy Comparison

It is necessary to compare solar energy to a present form of energy which we are all familar so that a direct comparison can be made. The form of energy selected was electrical.

An interview was obtained with Mr. Michael Manning who is residential sales representative with Georgia Power Company in their regional office in Athens, Georgia. The interview netted much information with regard to electrical utilization of energy in Georgia. Therefore, using electrical energy as a base to compare solar energy and thus give

the home owner a yardstick by which to measure the worthines of solar energy to his individual needs.

The following areas were considered and compared with electrical energy:

1. The cost of the system: an average house of 1000 square feet requiring 28,826 BTUs per hour was used as a model. a comparison was made of the electrical system needed for this size house with a solar system capable of supplying the same amount of heat, giving one an opportunity of looking at the initial cost of the system of solar versus electrical. Slso to be compared is solar hot water heating systems with a conventional electrical hot water system, furnishing a sufficient quanity of water for dishwashing, laundry, and any other hot water needs that are in the house.

2. The construction: a comparison of the construction of a conventional electrical system to that of a solar system for both hot water and heating purposes was made. This allowed a comparison of the size of the unit necessary to furnish the energy requried for the two systems.

3. Maintenance: the system whether electric or solar requires some periodic maintenance. The evalustion of electrical maintenance compared to solar maintenance for the house heating system

and the hot water heating system was helpful in determining the annual operating cost.

4. Temperature: This applies mostly to solar heating but does have some application toward electrical because the outside air temperature, during the winter, would have an affect on how often one used the electrical system. Since the solar system is entirely dependant on solar radiation, the air temperature would definately have an affect on how often one used the solar heating system and how much heat would be obtained from it.

5. The payout time: it is necessary to furnish the home owner with some type of break even point that he might consider in a long term investment in a heating system or hot water heating system. This done in terms of annual operating cost would tell the home owner how long it would take the system to pay for itself and also help one decide what type of construction would demand utilization of solar energy.

Summary

There are numerous companies who manufacture solar energy equipment with sufficient capacity to meet the needs of the home owner. Through comparison of the annual cost, construction, maintaince, temperature, and payout

time of the electric heating and hot water heater systems versus the solar heating and hot water systems, an economic as well as moral incentive to utilize solar energy can be achieved.

CHAPTER IV

ANALYSIS OF DATA

The information contained herein compares the cost, the construction, the maintenance, application, and payout time of solar heating and hot water systems with electric heating and hot water systems. It was considered to be installed in a house such as described in Table II. Figures were converted to a 1000 square footage base to make computations easy and allow easy comparison with any particular house. The initial cost of an electric heat pump equipment is $1400.00; plumbing, $25.00; electrical wiring assuming that the service entrance and panel are adequate, $150.00; duct work required to move the air through the house $400.00; concrete slab for the outdoor unit, $25.00; the equipment installation, labor and miscellaneous $200.00 for a total cost of installing a heat pump of $2000.00 (26, p. 43).

The solar system described by Helio Associates (21, p. 19) has an ititial cost of $500.00, and installation costs including electrical wiring, external heat storage unit, labor, and miscellaneous of $1000.00. The total cost of the solar heating system would be $1500.00. However, this is only a supplimental system and not a primary system, and therefore

would require the electrical system as a backup unit. The solar heating system described by Helio is capable of furnishing up to half the necessary requirements for house heating, thus reducing the annual operating cost which will be discussed in the payout time.

The initial cost per house for an automatic storage water heater of thirty-gallon capacity, electrically operated, is $115.00. Such a water heater has a galvanized steel tank and an estimated service life of ten years. A lined tank which has cement, glass, porcelain or similar lining has a service life of twenty years and an initial cost of $145.00. The electric hot water can be connected directly to the hot water lines providing the service panel and wiring are adequate. The water heater requires 4219 kilowatt hours per year of operation. At an average cost of two cents per kilowatt, this is $84.38 for electricity alone. The annual expense for maintenance and repairs is one per cent of the initial cost (26, p. 14).

The solar hot water heater can be constructed for $150.00 initial cost and another $75.00 for installation. It requires a solar collector heat storage tank and associated plumbing. Annual operating cost is $36.00 per year for the circulation pump to circulate the water through the solar collector. There are no additional costs except for the manufacturing if a solar heating system is used. The water from the incoming supply is simply sent through

the system. The cost of the coils in the heat storage tank is $50.00 (15, p. 4).

The Construction

The heat pump unit for furnishing the needs of the house described on page 9 would have a height of thirty-two inches, width of twenty-two inches, and depth of twenty-two inches. This is for the outdoor unit only. the indoor unit would have a vertical height of fifty-three inches, a width of twenty-two and one-half inches, and a depth of eighteen inches.

The size of a hot water heater thirty-gallon capacity is five feet high two feet in diameter. The electrical heat pump requires only the insulation and duct work to channel the air through the house and connections for electrical facilities.

The construction of the solar heating panels and heat storage bin is more complicated but can be accomplished by the do-it-yourselfer. The collectors must be built facing the sun during the major part of the day. The amount of the collector surface area needed is equal to one-half the floor ares of the house. the roof may be used to house the collectors, or they may be placed external to the house itself. The roof construction detracts less from the beauty of the house than would external construction of collector panels.(8).

The heat storage bin must also be constructed. There are several types available. There are types which utilize

water; an enclosed tank, insulated, located either above the ground filled with rocks through which water or air circulates and used to store heat brought to them from the collector panels. A 2000 gallon water heat storage tank is required to store enough heat for five cloudy days utilizing solar energy as a heat source (8).

A horizontal rock bin can also be made with packed sand and gravel. Porous rock is placed in the bottom with smaller rock placed on top. The two are seperated by wire mesh. The top of the bin is insulated and weather proofed to keep rain water out of the bin.

The use of solar heating for mobile homes is convenient since a horizontal heat storage can be placed under the mobile home itself. In this case, one will have a pleasantly warm floor and may not even need a duct to flow the warm air directly into the living space depending upon the floor insulation.

A heat storage bin can also be placed in a house basement. The duct for the warm air from the collector by way of the bin can be feed into the home heating system. Only a cold air duct from one room is then necessary to feed air to the collector for heating (21).

A solar hot water heater system may be made by placing the collector on the roof of the house and an insulated hot water storage bin in the attic, external to the building, or in the basement. The water is then circulated through

the collector returned to the hot water storage tank which should have a capacity of three or four times the total capacity needed during peak hot water flow periods of operation. The heat storage collector was connected to the hot water line in the house through a coil of pipe in the collector tank and the water pressure from the local water supply source was used to force the water through the system. A circulating pump was included to raise the water temperature. See Figures III and IV for a comparison of parts and principles of operation of the electrical and solar hot water heaters, page 34.

The Maintenance

The maintenance of an electrical heat pump system involves the following things: bi-annual changes in the filters of the system because of the collection of dirt and dust particles in these filters, the oiling and lubrication of the circulating fan, and servicing of the compression unit used to exchange the heat, or servicing of the heat pump itself. It is recommended by the manufacturer that these be done when a switch-over occurs from heating to cooling or from cooling to heating. With the addition of solar heating panels and solar heat storage tank the heat pump unit itself would be required to operate less hours. However, the fan, the pulleys, and belt associated with it and the filters in the system would still require the normal maintenance. Also maintenance of the solar system

FIGURE III

QUICK RECOVERY ELECTRIC WATER HEATER

A. TANK

B. HEATING UNITS

C. THERMOSTATS

D. COLD WATER INLET

E. HOT WATER OUTLET

F. DRAIN VALVE

G. PRESSURE RELIEF VALVE

H. INSULATION

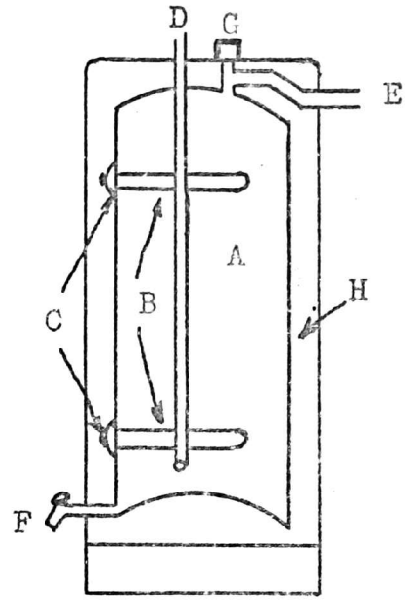
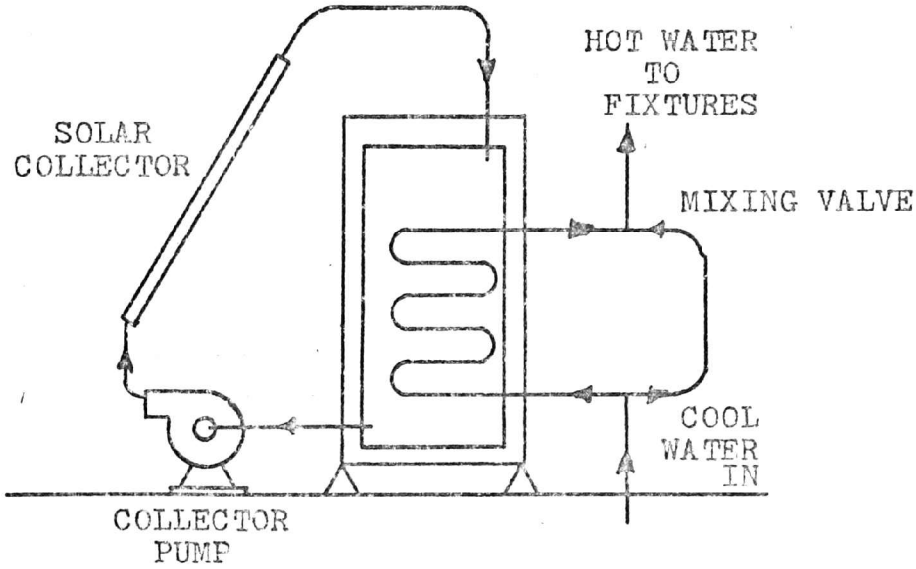


FIGURE IV

SOLAR HOT WATER HEATER



itself during the winter would involve adding enough anti-freeze to protect it from freeze-ups during the winter. This is necessary although it will find its maximum utilization during the winter or at night when the solar collector panels are not in use. Under these conditions a liquidfied system would freeze. A hot air system would be unaffected by this change, and certainly this should be considered.

A hot water heating system using an electrical hot water heater requires only periodic draining of the system to remove rust and other impurities which may collect in the bottom around the electrical heater unit (26, p. 19).

The solar hot water heat system should be filled with some type of anti-freeze to protect it during the winter months if it is a liquid system. If it is a hot air system, it requires no protection from freezing. However, during extremely warm summer days it may be necessary to circulate cool air through a hot air system to prevent it from overheating and burning up the collector panel. The solar hot water heating system would require periodic checks for such things as lubrication of the circulation pump (21, p. 18).

Temperature

The outside air temperature would affect the utilization of solar energy. If it is a very cold climate, which exists three months out of the year here in Georgia, the size of the solar heat storage tank will need to be increased

accordingly. Throughout Georgia there are between 2700 and 2900 hours of sunshine annually (8, p. 29). This sunshine aids electrical heating systems as well as furnishing the heat source for solar heating systems. The placement of the house relative to the sun can affect its utilization of radiant heat when an electrical system is installed. With the solar system, the placement of the house is not as critical since the collectors can be mounted to take maximum advantage of the sun. Limited detraction from the beauty of the house can be obtained however, if the house is positioned so that the solar panel may be located on the roof structure itself. The lack of a tremendous temperature differential year-round for Georgia makes the utilization of solar energy more practical than in states further North.

The designed temperature for heating systems in Georgia has a minimum outside temperature of plus ten degrees Fahrenheit, maintained inside temperature of plus seventy-two degrees Fahrenheit. The temperature differential is sixty-two degrees.

Payout Time

The payout time when utilizing solar energy to supplement heating systems and hot water systems is directly related to the annual operating cost and owning cost of each system whether electric or solar and electric. Table III is a comparison of the average annual owning costs for each

heating system. Table IV page 39 is a comparison of the annual operating cost of the hot water system as of June, 1974.

With the system reducing the energy requirements by fifty per cent from the electrical, the utilization of solar energy would reduce the electrical energy required by one-half plus the cost to run the electric pump or fan circulating the water or air in the solar system.

There is one drawback to the solar system and that is its need to be protected with some type of anti-freeze which will prevent the water from freezing in the lines during the winter nights when the water is not circulating. This can be accomplished by circulating a small amount of heated water from the heat storage tank through the pipes during the night to keep the temperature above thirty-two degrees Fahrenheit. This can be done by an electrically controlled thermostat to sense coil temperature and maintain it at or above thirty-two degrees Fahrenheit.

Hot water heating systems have a payout time when compared to solar. Hot water heaters have what is known as peak loads. These come between the hours of 7:00 A.M. and 9:00 A.M., and 6:00 P.M. and 8:00 P.M. in the evening. During thses critical times the amount of hot water will depend upon the sizes of the tank as well as the heater's ability to heat water quickly. These peak loads occur when the family is most likely to use the greatest amounts of hot water. It might be noted that in utilizing

TABLE III

AVERAGE ANNUAL OWNING COSTS

HEATING SYSTEMS

Factors Considered	Electric Heat Pump	Solar and Electric Heat Pump
1. Interest (8%)*	$160.00	$280.00
2. Taxes and Insurance (4%)	80.00	140.00
3. Allocation for Replacement (15 years per FHA)	133.33	233.33
4. Operating Costs Per Year	220.00	140.72
5. Maintenance Costs Per Year	60.00	50.00
Total--Annual Owning and Operating Costs	$653.33	$844.05

*Interest cost should be calculated on basis of the type of financing available.

ANNUAL OPERATING COSTS OF

THE SOLAR SYSTEM CALCULATIONS

Circulating fan. . . . . 43 Kilowatt hours

Dehumifider. . . . . .377 Kilowatt hours

Air Cleaner. . . . . .216 Kilowatt hours

Circulating Pump . . . . . .900 Kilowatt hours

1,536

1,536 X $.02 (per kilowatt hour) = $30.72

TABLE IV

AVERAGE ANNUAL OWNING COSTS

HOT WATER SYSTEMS

Factors Considered	Electric Hot Water Tank		Solar Hot Water System
	Galvanized	Lined	
Interest (8%)	$ 9.20	$11.60	$18.00
Taxes and Insurance (4%)	4.60	5.80	9.00
Allocation for Replacemtn (15 Years Per FHA)	11.50	7.25	-0-*
Operating Costs Per Year	84.38	84.38	36.00
Maintenance Costs Per Year	1.45	1.45	2.25
Totals	$111.13	$110.48	$65.25

*Available with a copper tank

solar energy the first peak load period is late afternoon would come after the solar system had gained its maximum heat and would be capable of delivering during this peak load period ample heat to incoming water. The second peak load period however, would require a heat storage tank since it would be following the night or dark during which no solar energy would be gained.

The comparison of the initial costs of the solar heating system indicates that the costs of the solar system is more expensive than the electric system at this time. Construction of the solar system is twice as large as the electric cystem, but can be easily accomplished in the house construction. The cost of maintenance of each system is equal for other systems. The affect of the outside air temperature has a greater negative affect on the solar system than the electric system. Annual owning cost for the solar house heater system is approximately $197.00 more per year and makes an economic incentive at this time not feasible. However, the solar hot water heater system is less expensive than conventional electric hot water systems and is economically desirable at this time.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS AND SUMMARY

As the supply of fossil fuels gets lower and the cost of conventional fuels gets more expensive, the use of solar energy becomes increasingly attractive. From the data available on solar energy certain conclusions and recommendations are evident for house owners.

It may be concluded that there is already solar energy utilization for house heating and hot water heating systems. Do-it-yourself guides to utilizing solar energy for the conventional house or relocatable housing (mobile house) are presently available. The solar systems may be integrated into the surroundings of the house with little or no degradatio of the architectural outlines of the house. The solar systems may even provide a privacy screen between houses or serve as part of the architectural design of the house itself in some cases.

The average annual owning costs of an electric heating system using a heat pump is found to be more economically feasible than solar interfaced with an electric heat pump. The cost of electrical energy will be less because fewer kilowatt hours will be used by the combination solar-electric

heat pump. The higher initial cost of the solar electric heat pump and the higher annual operating cost can be justified by realizing that in the state of Georgia, 5,464,700 kilowatts are generated by steam plants throughout the state. Only 433,180 kilowatts is generated by hydro-electric plants and at present only 1,179,000 kilowatts are generated by other means. Therefore, it may be concluded that the reduction of the number of kilowatts required for home heating would reduce the fossil fuels being burned to generate steam in the steam plants. The use of solar energy will save our fossil fuels which can not be replaced and will provide us with clean, free energy for heating our houses or hot water systems for our houses

It is recommended that the solar collector panels and heat storage tanks for house heating systems or solar hot water heating systems interface with the existing structure or be included in the architectural design of the house itself because of the high cost of real estate. It is not advisable to occupy land surrounding the house with material that could be placed on the house itself and thereby utilize the house to its fullest extent. An immediate recommended use for solar energy is for persons who have a second or vacation home where it is not feasible to continually supply it with energy year round by keeping it attached to the local services. Through the use of solar energy, it would be

possible to furnish all the heating and electrical needs for this second house in an area where utilities would be prohibitively high and the usage of these systems would be short-term with long no-load periods in between for the storage of energy. This fact alone suggests the need for more research in these areas, especially electrically power generation whether solar or wind driven to provide man's needs of energy.

Until solar energy is more widely used, a conscious effort must be made to reduce the consumption of energy, solar or electric. Adequate insulation can reduce the cost of house heating by as much as forty-five per cent. Storm windown, or double insulated glass, can reduce heating bills by up to twenty per cent. Thermostat settings can drastically affect the heating cost. One should select the lowest comfortable temperature in winter for more economical operation. This does not require the system to overwork itself to maintain an extremely high temperature inside the house (18).

There is great public interest in solar utilization. Following sensible recommendations on energy conservation, much energy can be saved while contributing to an extension of our fossil fuels. Solar heating and hot water systems are available for house owners to utilize the sun's energy

at this time. Combined with existing heating and hot water systems, solar energy can feasibly suppliment heating systems for Georgia house owners.

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