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ABSTRACT

This pamphlet reviews the direct transfer of solar energy into heat, particularly for the purpose of providing space and hot water heating needs. Owners of buildings and homes are provided with a basic understanding of solar heating and hot water systems: what they are, how they perform, the energy savings possible, and the cost factors involved. Both liquid and air solar collection systems are practical today. For convenience, most of the examples given relate to liquid systems. (Author/MLF)

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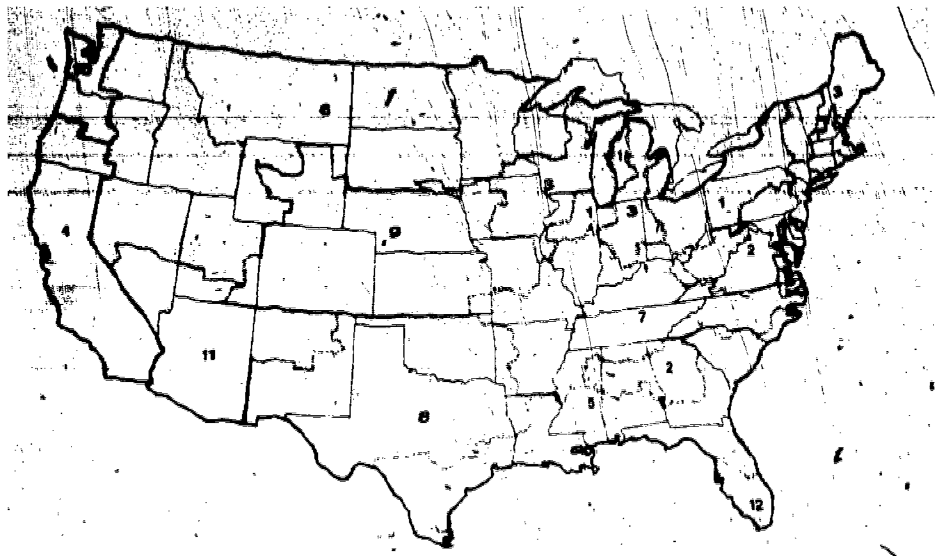

Table 1—Breakdown of zones by state. Numbers in parentheses following each state indicate zones included in that state.

ALABAMA (2, 5, 7)	MAINE (3)	OHIO (1, 2, 3, 7)
ARIZONA (11)	MARYLAND (2)	OKLAHOMA (7, 8)
ARKANSAS (7, 8)	MASSACHUSETTS (3)	OREGON (4, 6, 10)
CALIFORNIA (4)	MICHIGAN (1, 3)	PENNSYLVANIA (1, 2)
COLORADO (9)	MINNESOTA (3, 6)	RHODE ISLAND (1)
CONNECTICUT (1, 2)	MISSISSIPPI (2, 5, 7)	SOUTH CAROLINA (5, 7)
DELAWARE (2)	MISSOURI (3, 7, 9)	SOUTH DAKOTA (6, 9)
FLORIDA (5, 12)	MONTANA (6)	TENNESSEE (7)
GEORGIA (2, 5, 7)	NEBRASKA (9)	TEXAS (5, 8)
IDAHO (6)	NEVADA (6, 11)	UTAH (6, 9, 11)
ILLINOIS (1, 3, 7)	NEW HAMPSHIRE (1, 3)	VERMONT (1, 3)
INDIANA (1, 3, 7)	NEW JERSEY (2)	VIRGINIA (2, 5, 7)
IOWA (3, 6, 9)	NEW MEXICO (8, 11)	WASHINGTON (6, 10)
KANSAS (7, 9)	NEW YORK (1, 2, 3)	WASHINGTON, D. C. (2)
KENTUCKY (2, 7)	NORTH CAROLINA (2, 5, 7)	WEST VIRGINIA (1, 2, 7)
LOUISIANA (5, 8)	NORTH DAKOTA (6)	WISCONSIN (3, 6)
		WYOMING (6, 9)

Solar Energy for Space Heating & Hot Water

Division of Solar Energy

Energy Research and Development Administration

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The United States is in the midst of a serious and continuing energy problem; we must seek new ways of meeting our energy demands. One possibility which has received a great deal of attention lately is capturing the sun's radiant energy falling upon the earth. Although there are several ways in which the sun's rays can be harnessed, this pamphlet reviews the direct transfer of solar energy into heat, particularly for the purpose of providing space and hot water-heating needs. This pamphlet provides building and home owners with a basic understanding of solar heating and hot water systems: what they are, how they perform, the energy savings possible and the cost factors involved. Both liquid and air solar collection systems are practical today. For convenience, most of the examples given in this pamphlet relate to liquid systems.

Availability of Solar Energy The amount of solar energy striking a square foot of the earth's surface varies throughout the United States. Climatic factors such as temperature, cloud cover, humidity, and wind affect the ways in which solar systems are useful. For these reasons, the contiguous United States has been divided into twelve (12) solar climatic zones. Table 1 and the map on the inside front cover of this pamphlet break down these zones by state. It should be noted that even within these zones significant climatic variations can occur in some areas.

Description of Solar Heating and Hot Water Systems Figure 1 outlines the basic elements of a solar heating and hot water system. The system as shown provides two basic functions: (1) capturing the sun's radiant energy, converting it into heat energy and storing this heat in an insulated energy storage tank; and (2) delivering the stored energy as needed to either the domestic hot water or heating system. The parts of the system which provide these two functions are referred to as the collection and delivery subsystems.

The key component in the collection subsystem is the collector. The basic function of the collector is to trap the sun's energy. Figure 2 gives a detailed view of a typical collector. The transparent cover plates made of glass or a suitable plastic material allow the rays of the sun to pass into the collector. Once inside the collector, the sun's rays are absorbed by a blackened metal absorber plate and transformed into heat energy. On sunny days absorber plate temperatures can reach well over 200° F. Insulation is placed

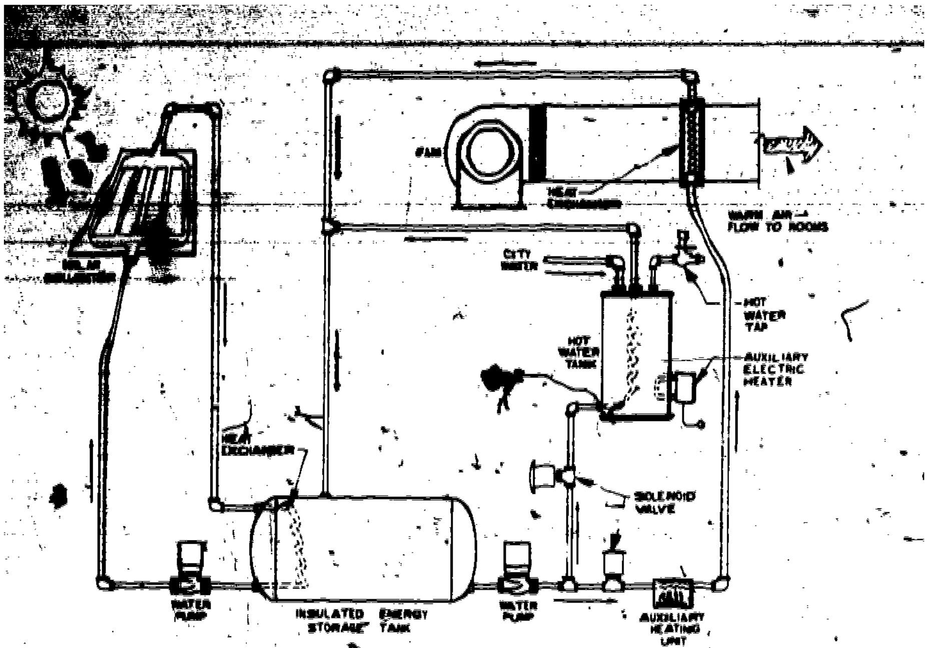

Figure 1. Schematic Diagram of a Solar Heating and Hot Water System.

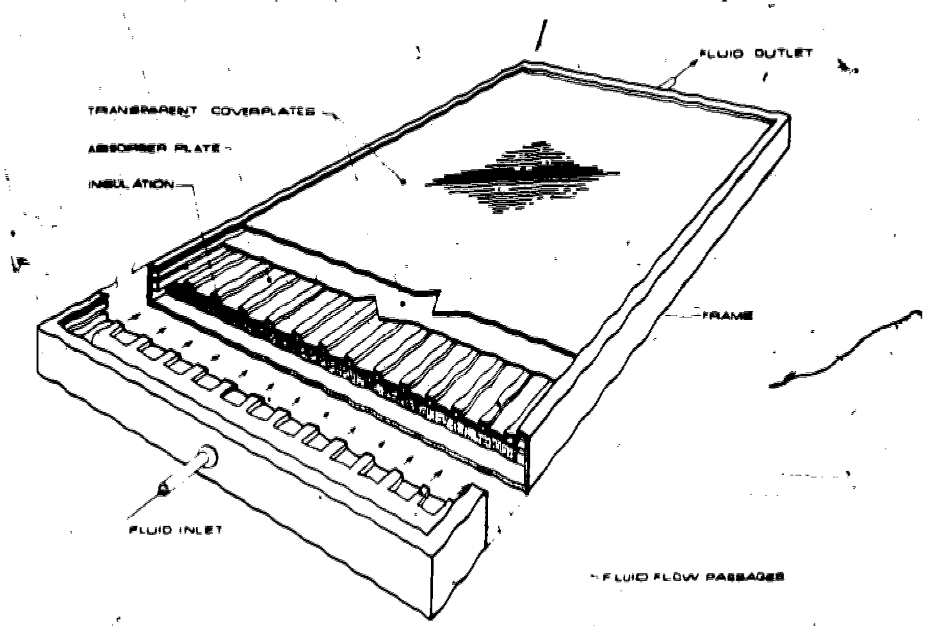

Figure 2. Detailed View of a Typical Solar Collector.

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under the absorber plate to prevent heat loss out of the back side of the collector. Coverplates prevent the loss of heat from the top side of the collector. They perform the same function as the glass in a greenhouse. Heat energy is removed from the collector by circulating a fluid, such as water, through tubes in the absorber plate or by passing air over or under the absorber plate. The heat energy so removed is carried by means of insulated pipes or ducts to an insulated energy storage tank near or in the building.

The energy storage tank, which may be full of a liquid such as water, stores the heat so that it may be withdrawn upon demand. The transfer of energy to the storage tank is accomplished by means of a heat exchanger. Examples of heat exchangers include coils of metal tubing, the radiators in automobiles, and the finned radiators in electric baseboard heating units. Storage tanks and collectors are usually sized to enable the system to supply enough energy to support the building heating and hot water requirements for a few consecutive cloudy days.

The delivery subsystem is divided into two parts: one for providing heat to the hot water tank and another for providing heat to the building heating system. When either the domestic hot water or heating system requires heat, hot water from the energy storage tank is pumped to a heat exchanger in the domestic hot water tank or in the building ducts. See Figure 1.

On occasions when the temperature in the energy storage tank falls below the required temperature, perhaps due to increased demand for heat during a cold spell, an auxiliary heating unit such as a furnace or electrical resistance heater is turned on to provide the needed energy.

A hot water tank, conventional heating unit, duct work, and some of the piping are already a part of many buildings. Just the addition of collectors, an insulated energy storage tank, and associated piping are required for a solar system. The actual placement of collectors and energy storage tanks in a given case depends upon such factors as building orientation, available space, and roof angle, in addition to aesthetic factors. Figures 3 and 4 picture solar collectors placed on the roof of a commercial building and a home.

What To Expect From a Solar System There is a most important question to be answered when designing a solar heating and hot water system: How many square feet of collector are required to meet the energy needs of the build-

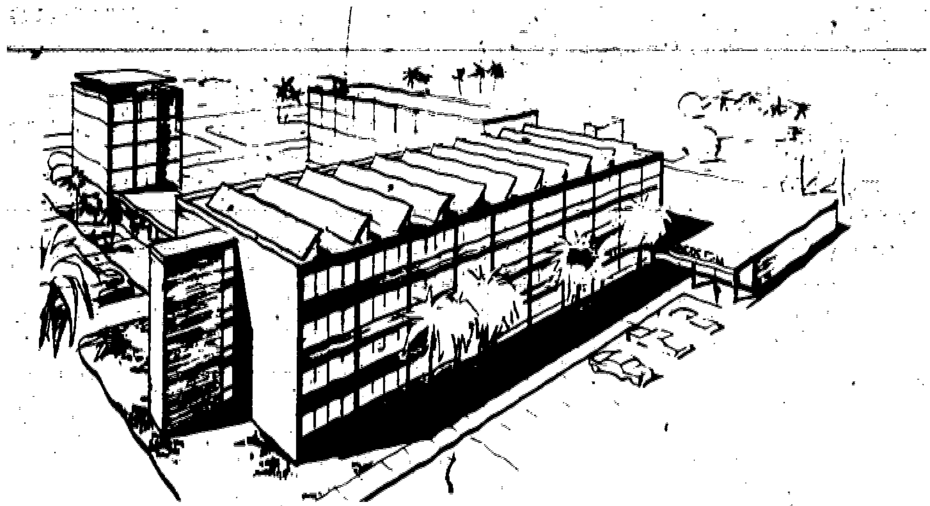

Figure 3. A Commercial Building With Solar Collectors on the Roof.

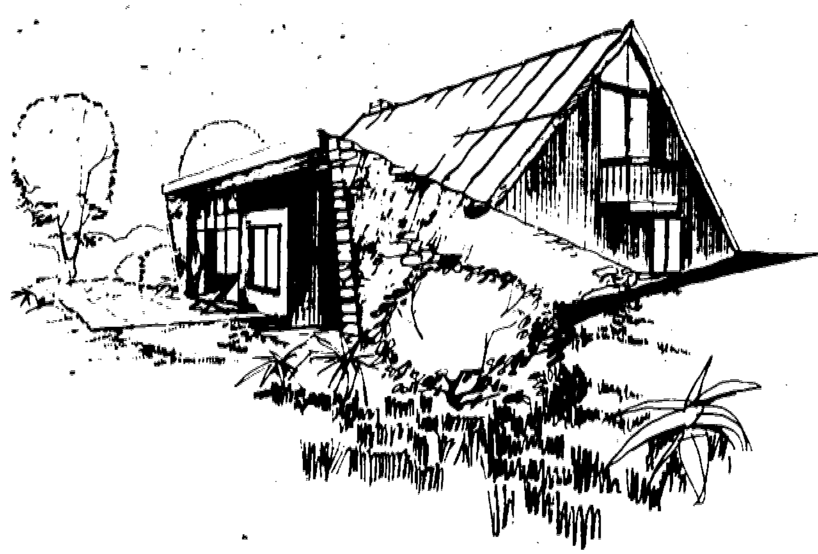

Figure 4. A Residence with Solar Collectors Incorporated Into the Roof.

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TABLE 2—APPROXIMATE COLLECTOR AND STORAGE TANK SIZES REQUIRED TO PROVIDE THE HEATING AND HOT WATER NEEDS OF A 1500 SQUARE FOOT HOME

Climatic Zone	Percent of Energy Supplied by Solar	Collector Area, Square Feet	Representative Collector Dimensions		Storage Tank Capacity, Gallons	Representative Cylindrical Storage Tank Dimensions	
			No. of 8-Ft. High Rows	Length of Each Row, Ft.		Diameter, Inches	Length, Inches
1	71	800	3	33	1,500	48	200
2	72	500	2	31	750	42	138
3	66	800	3	33	1,500	48	200
4	73	300	1	37.5	500	48	78
5	75	200	1	25	280	42	60
6	70	750	3	31	1,500	48	200
7	70	500	2	31	750	42	138
8	71	200	1	25	280	42	60
9	72	600	2	37.5	1,000	48	132
10	58	500	2	31	750	42	138
11	85	200	1	25	280	42	60
12*	85	45	1	5.5	80	20	63

*Includes only hot water needs.

ing? To answer this question, a chart indicating radiant energy available, collected, and required might be prepared. Charts 1-12 were prepared for a 1500 square foot house located in each Climatic Zone. For each month, an estimate of both the building heating and hot water energy requirements has been indicated by the righthand bar. The lefthand bar indicates the solar energy which is available on the indicated square footage of collectors tilted to an appropriate angle (approximately the local latitude angle) along with the amount of this energy which typically can be collected.

Note that for the months of November through March the energy requirements are usually greater than the solar energy collected. During the rest of the year more energy is

TABLE [illegible]—APPROXIMATE COLLECTOR AND STORAGE TANK SIZES REQUIRED TO PROVIDE THE HEATING NEEDS OF A 10,000 SQUARE FOOT BUILDING LOCATED IN EACH CLIMATIC ZONE

Climatic Zone	Percent of Energy Supplied by Solar	Collector Area, Square Feet	Representative Collector Dimensions: No. of 8-Ft. High Rows	Representative Collector Dimensions: Length of Each Row, Ft.	Storage Tank Capacity, Gallons	Representative Cylindrical Storage Tank Dimensions: Diameter, Inches	Representative Cylindrical Storage Tank Dimensions: Length, Inches
1	74	5,330	7	95	10,000	96	326
2	71	3,330	5	83	5,000	72	300
3	68	5,330	7	95	10,000	96	326
4	73	2,000	4	62.5	4,000	72	246
5	75	1,210	3	50.5	2,000	54	215
6	72	5,000	7	89	7,500	84	322
7	71	3,330	5	83	5,000	72	300
8	74	1,330	3	55.5	2,000	54	215
9	75	4,000	6	83	6,000	72	354
10	60	3,330	5	83	5,000	72	300
11	77	1,000	3	41.5	1,500	54	168
12	*						

* There is essentially no heating requirement in this zone.

collected than needed and this excess energy is then discarded. A greater proportion of the winter heating needs could be met by installing more collector area; however, this adds to the cost. Instead, it is usually more economical to reduce the heating requirements by installing more insulation, storm windows, and other energy conserving features. In the chart examples, between 55 and 85 percent of the yearly heating and hot-water energy requirements are supplied by solar energy. Most solar systems are designed to supply between 50 and 80 percent of the yearly heating and hot water energy requirements.

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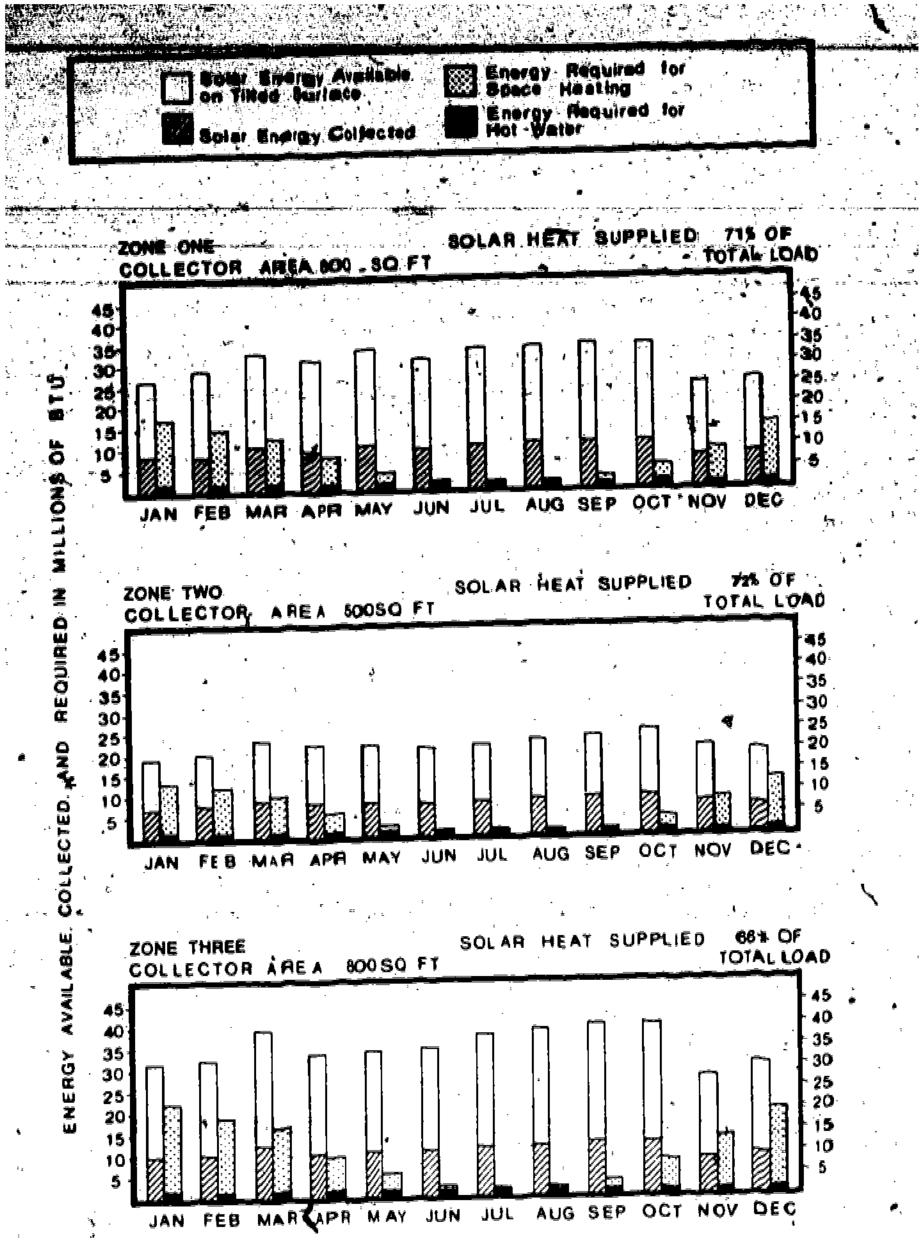
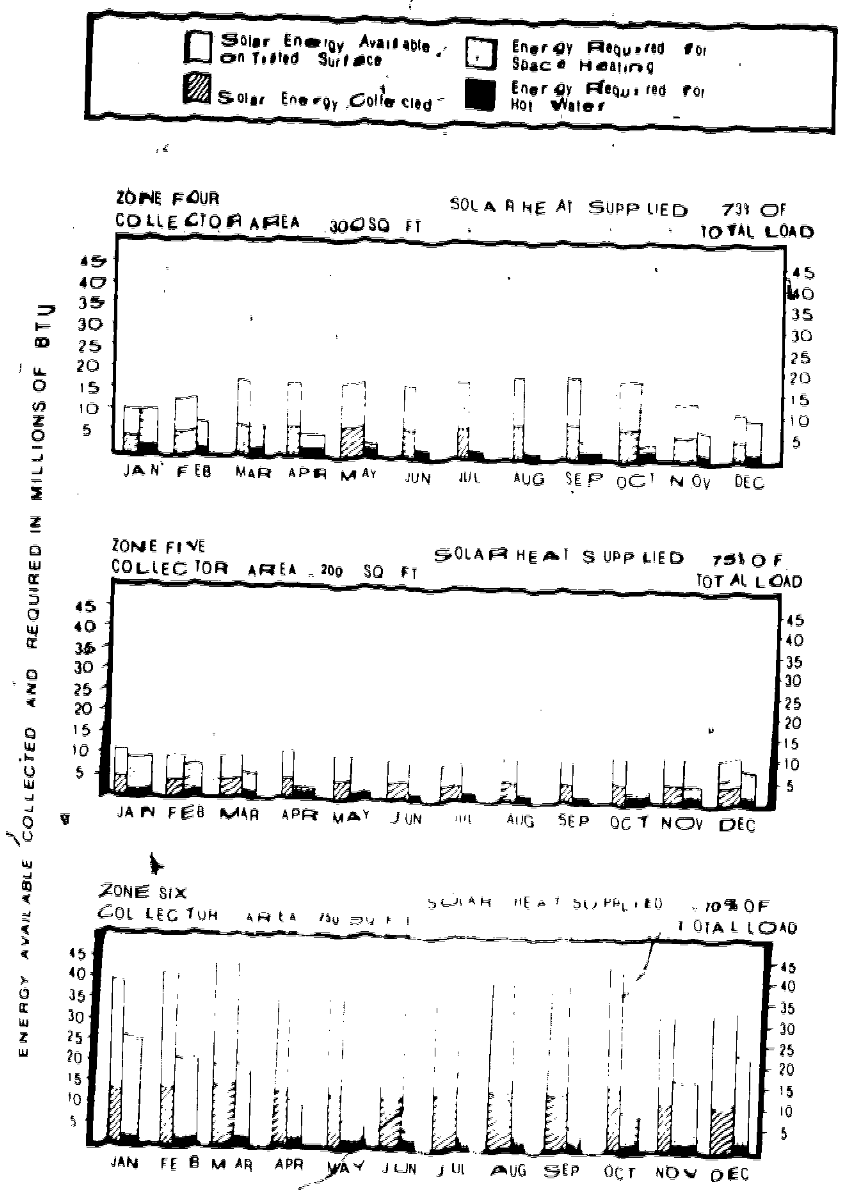
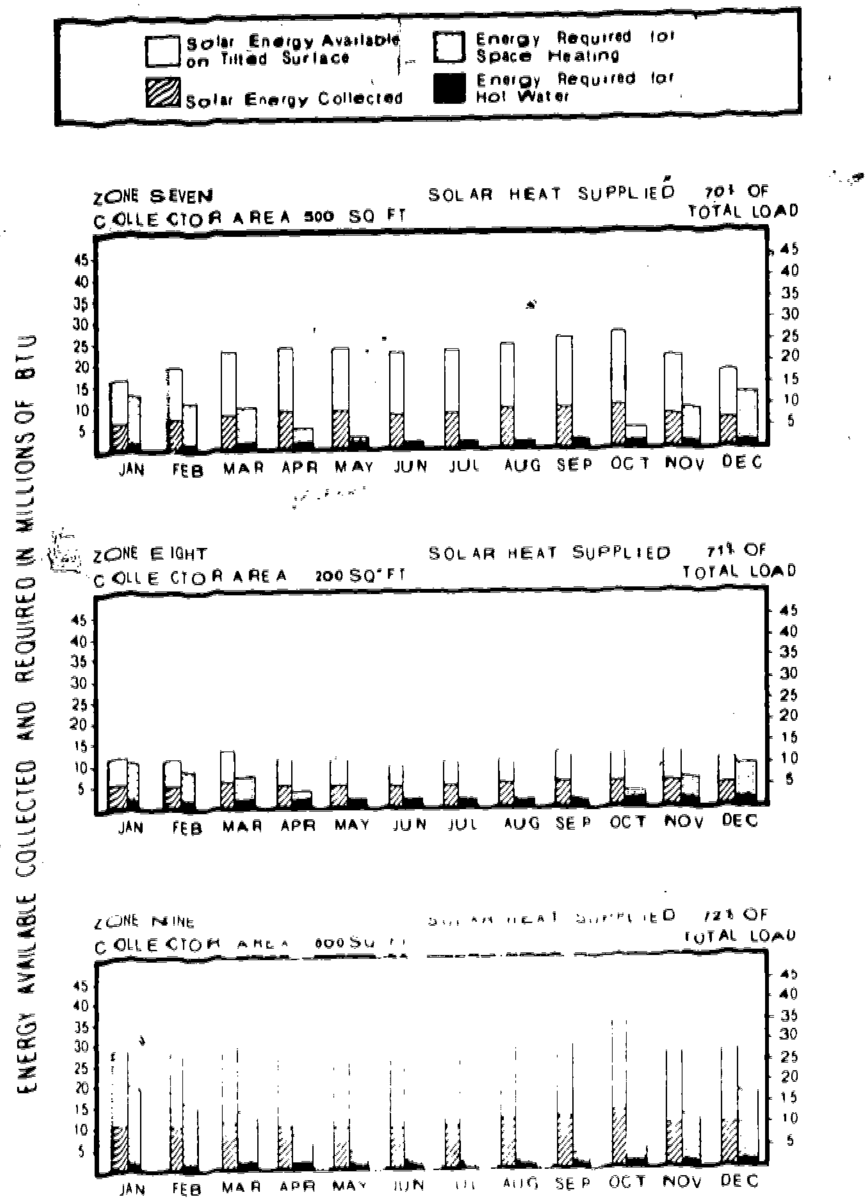


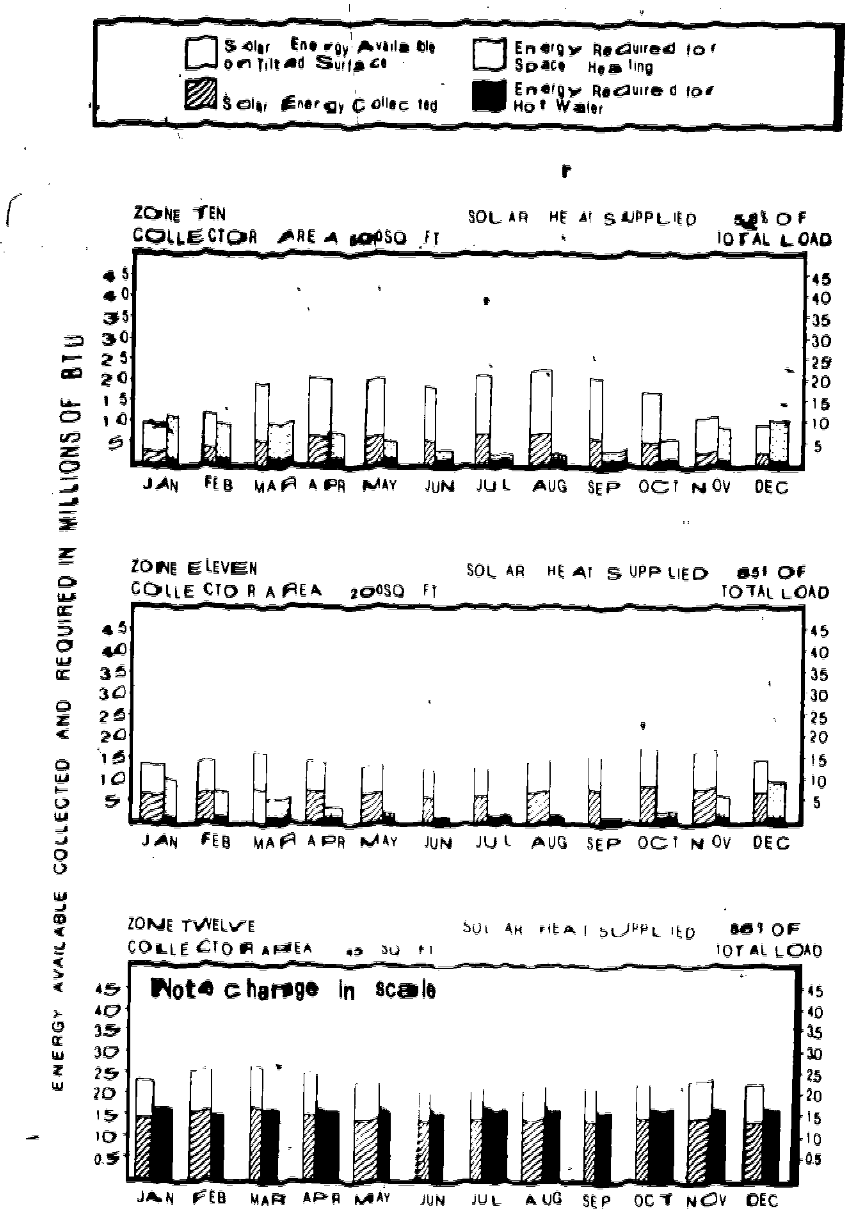
CHARTS 1-3. Energy Available, Collected and Required For a 1,500 Square Foot House Located in Climatic Zones 1-3.



CHARTS 4-6. Energy Available, Collected and Required For a 1,500 Square Foot House Located in Climatic Zones 4-6.



CHARTS 7-9 Energy Available, Collected and Required For a 1,500 Square Foot House Located in Climatic Zones 7-9.



CHARTS 10-12. Energy Available, Collected and Required For a 1,500 Square Foot House Located in Climatic Zones 10–12.

Table 3a Energy Supplied and Annual Dollar Savings (1500 Square Foot Building)

Climatic zones	Energy savings, millions of BTUs	Comparison with oil		Comparison with electricity		
		Equivalent gallons	Dollar savings *	Equivalent kilowatt * hours	Dollar savings at indicated cost	Cost per kWh
1	67.9	767	303	19,900	995	5¢
2	54.9	612	245	16,000	720	4.5¢
3	82.0	914	366	24,000	960	4.5¢
4	41.8	466	186	12,200	488	4¢
5	33.8	377	151	9,900	347	3.5¢
6	98.9	1,103	441	29,000	1,015	3.5¢
7	50.6	564	226	14,800	518	3.5¢
8	39.0	435	174	11,400	399	3.5¢
9	74.6	832	333	21,900	767	3.5¢
10	46.5	518	207	13,600	272	2¢
11	43.7	487	195	12,800	512	4¢
12	16.7	186	74	4,900	196	4¢

* 65% furnace efficiency at 40¢/gallon

The size of the energy storage tank can vary widely. A good rule of thumb is that in a system using water, about 1½ gallons of storage capacity should be available for each square foot of collector used. For air systems which usually store energy in rocks, a storage volume of about three (3) times that of a water system is used. Tables 2a and 2b outline the approximate collector area and storage tank size required to provide the indicated portion of the yearly heating and hot water energy requirements for buildings of 1500 and 10,000 square feet located in each of the Climatic Zones.

Energy Savings Based upon the collector areas shown in Tables 2a and 2b for buildings of 1500 and 10,000 square feet and on the heating and hot water energy requirements for these buildings in each Climatic Zones, the energy savings calculated are shown in Tables 3a and 3b.

Solar System Costs and Dollar Savings Traditionally, a large number of items sold in the United States have been purchased on the basis of initial cost with slight attention to maintenance and operating costs Examples are homes, automobiles, air conditioners, and heating systems With the rapid escalation of fuel prices though, the operating costs for energy consuming items have become very important It is

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Table 3b—Solar Energy Supplied and Annual Dollar Savings

(10,000 Square Foot Building)

Climatic zone	Energy savings, millions of BTUs	Comparison with oil: Equivalent gallons	Comparison with oil: Dollar savings **	Comparison with electricity: Equivalent kilowatt hours	Comparison with electricity: Dollar savings at indicated cost	Comparison with electricity: Cost per kWh
1	372	4,147	1,659	109,000	5,450	5¢
2	268	2,988	1,195	78,500	3,530	4.5¢
3	472	5,262	2,015	138,300	6,220	4.5¢
4	186	2,074	830	54,500	2,180	4¢
5	128	1,427	571	37,500	1,310	3.5¢
6	587	6,544	2,618	172,000	6,020	3.5¢
7	253	2,821	1,128	74,100	2,594	3.5¢
8	174	1,940	776	51,000	1,784	3.5¢
9	418	4,660	1,864	122,500	4,290	3.5¢
10	242	2,698	1,079	70,900	1,420	2¢
11	165	1,839	736	48,300	1,930	4¢
12	*					

* There is essentially no heating requirement in this Zone
** 65% furnace efficiency at 40¢/gallon

now worth considering whether greater initial expense for a solar system which consumes essentially no external fuel will result in savings in the long run. Today's solar system costs are high because the solar industry has not yet developed cost-reducing, mass-production methods. Yet, the operating costs of solar systems are much less than the operating costs of conventional energy systems.

Table 4 lists a range of prices which a building or home owner could expect to pay for the solar systems shown in Tables 2a and 2b. These approximate costs include design, materials, and installation of the entire solar system.

Even though the solar systems' costs in Table 4 are rather high, a number of factors tend to make the future of solar heating and hot water systems look good. These include the rising prices of oil, gas, and electricity, and the expected decrease in solar system costs as better production techniques are developed. In addition, design and installation costs will decrease as experience in those areas is gained.

How to Use this Pamphlet The following example is given in order to demonstrate how to use the information in this pamphlet. Suppose an owner resides in the Washington, D.C. area. According to Table 1 and the map on the inside cover, Washington, D.C. and the surrounding areas are in Climatic Zone 2. Table 2a indicates that for a 1500 square foot home in Climatic Zone 2, 500 square feet of collector and a 750 gallon energy storage tank will provide 72% of the heating and hot water energy needs. The information in Table 3a indicates that for Climatic Zone 2, it is possible to save 612 gallons of oil annually, which is equivalent to $245 at 40¢/gallon, or 16,000 kilowatt-hours of electricity annually, which is equivalent to $720 at 4.5¢/kWh. Table 4 indicates that the cost of the solar system will be in the range of $5,000 - $15,000.

Table 4—Range of Solar Heating and Hot Water System Costs For 1,500 and 10,000 Square Foot Buildings Located in Each Climatic Zone.

Climatic Zone	Range of Solar System Costs for a 1,500 Square Foot Home	Range of Solar System Costs for a 10,000 Square Foot Building
1	$8,000 — $24,000	$53,000 — $159,000
2	$5,000 — $15,000	$33,000 — $ 99,000
3	$8,000 — $24,000	$53,000 — $159,000
4	$3,000 — $ 9,000	$20,000 — $ 60,000
5	$2,000 — $ 6,000	$13,000 — $ 39,000
6	$7,500 — $22,500	$50,000 — $150,000
7	$5,000 — $15,000	$33,000 — $ 99,000
8	$2,000 — $ 6,000	$13,000 — $ 39,000
9	$6,000 — $18,000	$40,000 — $120,000
10	$5,000 — $15,000	$33,000 — $ 99,000
11	$2,000 — $ 6,000	$13,000 — $ 39,000
12	$ 450 — $ 1,350	

Role of the Federal Government The reader, here, has been provided with a basic understanding of solar heating and hot water systems. Because of the energy problems we are facing in the United States, it is important that alternate energy sources are developed as rapidly as possible. The United States Energy Research and Development Administration (ERDA) was created by Congress for the purpose of insuring that this nation has adequate supplies of energy to meet our needs. As part of its program, ERDA is pursuing a vigorous program in the solar energy field. The overall goal of the Federal program is to stimulate an industrial and commercial capability for producing and distributing solar heating and cooling systems, thus reducing the demand in present fuel supplies through widespread use of these systems in residential and commercial buildings. Other government agencies such as the Department of Housing and Urban Development, The National Aeronautics and Space Administration, the National Bureau of Standards, and the Federal Energy Administration are assisting ERDA in its solar energy activities.

Further information on the availability of solar heating and cooling equipment may be obtained from:

Solar Energy Industries Association
1001 Connecticut Avenue, N.W.
Washington, D.C. 20036

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) can send you names and addresses of members of their Technical Committee on Solar Energy Utilization. Committee members themselves can help you plan for a solar home heating system or refer you to other engineers in your area who can help.

ASHRAE
Director of Research and Technical Services
345 East 47th Street
New York, NY 10017

The National Association of Home Builders can also provide advice on planning solar installations

NAHB Research Foundation, Inc
P. O. Box 1627
Rockville, MD 20850

Detailed information on specific products may be obtained from ERDA-75 "Catalog on Solar Heating and Cooling Products", order number ERDA 75 052-010-00470-1 ($3.80) This document may be ordered from.

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For professional design and engineering advice on solar installations consult local architects design engineers, and members of the American Society of Heating Refrigerating and Air Conditioning Engineers