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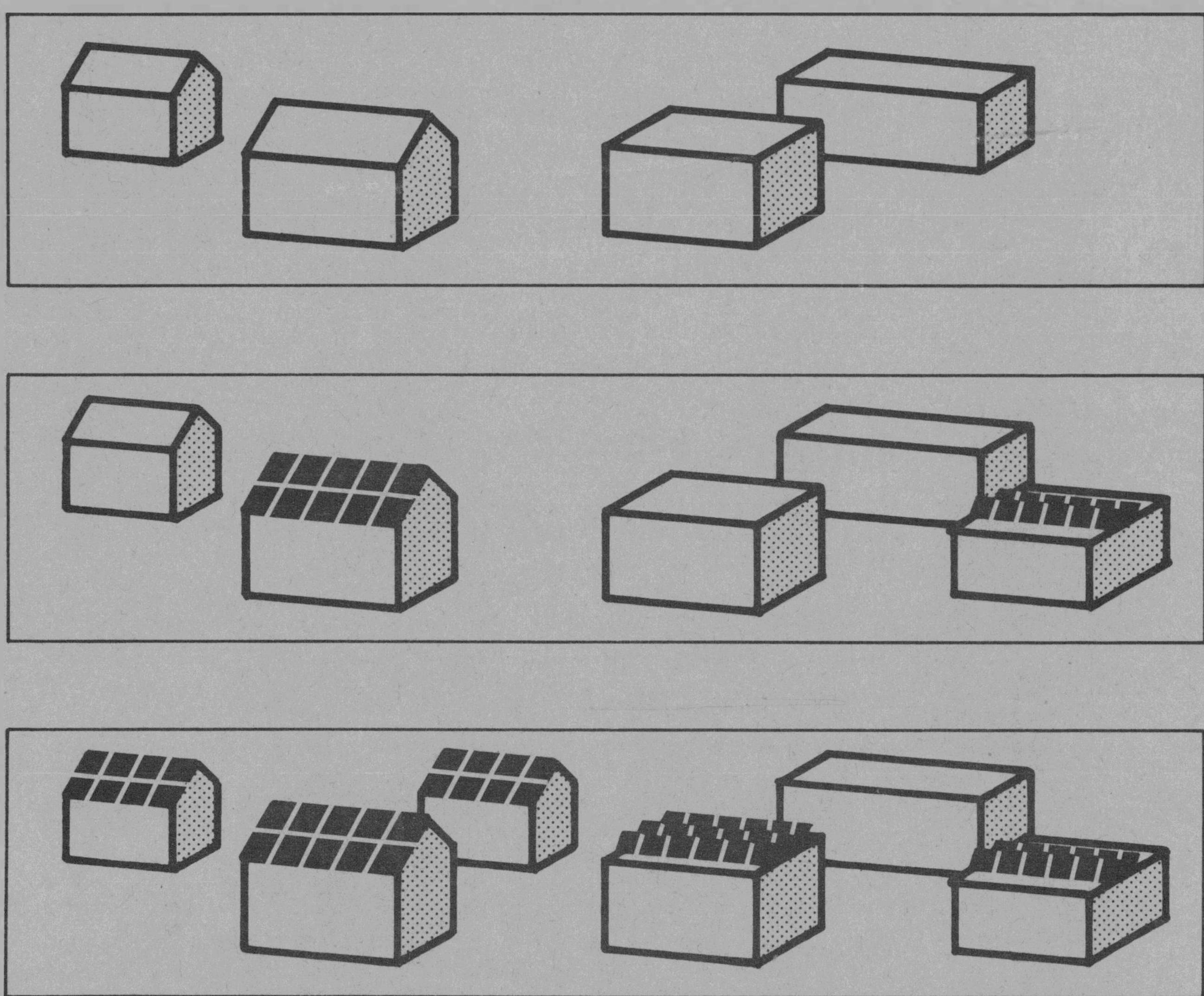
SOLAR HEATING AND COOLING OF BUILDINGS (SHACOB)

Commercialization Report

PART A

Volume III - Appendices



Federal Energy Administration

Task Force on Solar Energy Commercialization

FEDERAL ENERGY ADMINISTRATION ACTIVITIES

The Federal Energy Administration (FEA) is involved with the development and use of solar energy encompassing a broad range of interests including: the direction of the nation's solar-related endeavors as part of our national energy strategy; the policy, planning and overall coordination of solar energy commercialization; and certain regulatory and resource management functions which affect the use of solar energy.

FEA's legislative authority for solar-related activities is based on a number of laws including PL 93-275, PL 93-438, and PL 94-385. Of significance, the Energy Conservation and Production Act (PL 94-385) authorizes FEA to "provide overall coordination of federal solar energy commercialization activities" and "to carry out a program to develop the policies, plans, implementation strategies, and program definitions for promoting the accelerated utilization and widespread commercialization of solar energy." As part of PL 94-385, the Congress listed several solar energy commercialization activities which it expects FEA to carry out, a few of which include:

- Develop a national plan for the accelerated commercialization of solar energy to include workable options for achieving on the order of 1 million barrels per day of oil equivalency in energy savings by 1985 from a combined total of <u>all</u> solar technologies;

- Develop commercialization plans for <u>each</u> major solar technology;

- Conduct studies and analyses addressing mitigation of economic, legal, environmental, and institutional constraints;

- Develop state solar energy commercialization plans and programs and coordinate with state energy conservation programs; and

- Develop such major commercialization projects as, but not limited to, the "Southwest Project," the "Solar Energy Government Buildings Project," among others.

SOLAR HEATING AND COOLING OF BUILDINGS (SHACOB)
COMMERCIALIZATION REPORT

OPTIONS AND STRATEGIES

PART A

VOLUME III - APPENDICES

FINAL REPORT

July 15, 1977

Prepared by:

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425 Volker Boulevard
Kansas City, Missouri 64110
FEA Contract No. CR-05-70065-00
MRI Project No. 4373-L

and

Federal Energy Administration
Task Force on Solar Energy Commercialization
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Washington, D.C. 20461

This report was prepared under contract to the Federal Energy Administration (FEA) and does not necessarily state or reflect the views, opinions, or policies of the FEA or the Federal Government.

PREFACE

The Energy Conservation and Production Act (PL 94-385) authorizes the Federal Energy Administration (FEA) to "provide overall coordination of federal solar energy commercialization activities" and "to carry out a program to develop the policies, plans, implementation strategies, and program definitions for promoting the accelerated utilization and widespread commercialization of solar energy." The Congressional conference report listed several specific actions desired by the Congress including (among others):

- Develop a national plan for the accelerated commercialization of solar energy to include workable options for achieving on the order of 1 million barrels per day of oil equivalency in energy savings by 1985 from a combined total of <u>all</u> solar technologies;*

- Develop commercialization plans for <u>each</u> major solar technology;

- Conduct studies and analyses addressing mitigation of economic, legal, environmental, and institutional constraints;

In essence, the "National Plan. . .for <u>all</u> solar technologies" will be comprised of the combination of "commercialization plans for <u>each</u> major solar technology." Analyses of costs, benefits, and strategy options for each of the technologies can be placed in context, coordinated and optimized into an overall commercialization plan for solar energy.

The SHACOB Commercialization Report (PARTS A and B) is the first step toward development of a SHACOB Commercialization <u>Plan</u>. PART A addresses <u>qualitatively</u> the potential barriers to and incentives for the accelerated commercialization of SHACOB in the residential and commercial sectors. It represents a summary and synthesis of a large amount of recently completed research on all aspects of the market development of solar heating and cooling. PART B, prepared by Arthur D. Little, Inc., under FEA Contract No. CR-05-70066, contains <u>quantitative</u> analyses of the market penetration and the costs and benefits to the government associated with some of the incentives examined in PART A.

The SHACOB Commercialization Report relates closely to the President's proposed National Energy Plan (NEP) in that it analyzes a large number of incentives in terms of their impact on barriers to commercialization, their impact on income and interest groups, and possible administrative mechanisms. The impacts of incentives contained in the NEP are analyzed and compared to the present research, development and demonstration programs, an expanded NEP, and new initiatives.

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* Major solar technologies include: solar heating (including hot water) and cooling of buildings--SHACOB, agricultural and industrial process heat, wind energy conversion systems, photovoltaics, fuels from biomass, solar thermal, and ocean thermal energy conversion.

PART A is divided into three volumes. Volume I is the executive summary. The technical report is presented in Volume II. Volume III contains appendices which support the technical discussions in Volume II.

PART A was prepared by Midwest Research Institute under FEA Contract No. CR-05-70065-00. The principal authors were Mr. Dennis Costello (Project Leader) and Mr. David Posner. They were assisted by Mr. Carl Bingham and Mr. Michael Scott. Consultants on the project were Dr. Ronal Larson, Georgia Institute of Technology, Mr. Jerry Bradley, Desert Research Institute, and Dr. Harold Orel, University of Kansas. The original draft material was partly supplied by members of the Federal Energy Administration's Task Force on Solar Energy Commercialization. Mr. Norman W. Lutkefedder is the Director of the Task Force. Other Task Force members are: Samuel J. Taylor (Deputy Director), LaVerne P. Johnson, Robert Grubermann, I-Ling Chow, Stanly Stephenson, Edward Downey, Mike Kutsch, Elaine Smith, Howard L. Walton, Richard D. Stoll, Howard Magnas, Charles Allen, Robert Jordan, Jeffrey Milstein, Margaret Sibley, Sally Mott, Ned Dearborn, James H. Berry, Mary Liebert, and Jack Koser.

Approved for:

MIDWEST RESEARCH INSTITUTE

L. J. Shannon

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INDUSTRY ACTIVITIES

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I. SOLAR COLLECTOR MANUFACTURING ACTIVITY JULY - DECEMBER 1976

The Office of Energy Information and Analysis within the Federal Energy Administration has completed its fifth semiannual survey of private firms that manufacture and sell solar collectors.* This survey covered the second half of calendar year 1976. The purpose of the survey is to obtain descriptive statistics on economic activity in the solar heating and cooling area and to identify production growth in this fledgling industry. Results show that production during the second half of 1976 was 73% greater than during the first half of 1976 and that total production for 1976 was 168% greater than that of 1975.

A. Methodology of Survey

Several different sources were used to generate lists of solar collector manufacturers. The basic list consisted of those companies that had previously reported the manufacture of collectors. Government agencies active in solar energy, such as the Energy Research and Development Administration and the Department of Housing and Urban Development, and state energy agencies were contacted for additional lists of potential collector manufacturers. Several solar energy magazines and regional solar energy associations were also contacted. As a result, over 350 companies were surveyed. Each potential manufacturer was asked whether they had been in production during the second 6 months of 1976, and if so, they were then asked several additional questions: How many square feet of collector had they manufactured and sold during that time period? What type(s) of collector(s) do they manufacture (i.e., air or liquid working medium; low-temperature, medium-temperature or special)? What are the applications of the collectors they have sold during this time period (i.e., pool heating, domestic hot water, space heating, space cooling, other)?

Companies reporting manufacture and sale of at least 100 sq ft of solar collector were included in the list, "Manufacturers of Solar Energy Collectors." Production of less than that amount was taken as an indication that the company had not yet entered the solar collector market.

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* This survey, which is reprinted in Sections I and II of this appendix, was prepared by Richard D. Stoll with the assistance of Charles Allen, Barry Roberts, Howard Magnas, Howard Walton and Patricia Nicholson, Nuclear and New Technologies Division, Office of Coal, Nuclear and Electric Power Analysis, Federal Energy Administration. An effort was made to include all solar collector manufacturers that produced and sold collectors during the July through December 1976 period. Any company that produced collectors during this period or expects to enter production is encouraged to contact FEA for inclusion in the next survey.

Care was taken to distinguish between collectors manufactured and collectors sold, so as to avoid double counting. The type of collector produced by each manufacturer is indicated in the list, "Manufacturers of Solar Energy Collectors," provided at the conclusion of the report.

B. Background

The solar energy collector is essentially a device for intercepting sunlight, converting the sunlight to heat, and carrying that heat to where it will be either used directly or stored for later use. Water or an anti-freeze solution are the most frequently used working media for transporting the heat, but special oils that can operate at high temperatures and air are also used in many systems.

In the most recent survey report, three broad classes of solar collectors were recognized: low-temperature, medium-temperature, and special. The medium-temperature collectors are made by more manufacturers than either of the other types. Medium-temperature collectors typically are composed of a metal absorber panel covered by a single or double glazing of glass or plastic, all within a rigid frame. They generally operate in the 140°F to 180°F temperature range, and are mainly used for space heating and domestic hot water heating, although they are also used for pool heating. Also in the category of medium-temperature flat-plate collectors are those with selective absorption-emission surfaces, double glazing, and other special features to allow them to operate up to 240°F or 250°F. These high-performance flat-plate collectors are designed to work with absorption coolers.

Low-temperature collectors are used almost exclusively to heat swimming pools. They are usually made of plastic or rubber and are designed to increase the temperature of large streams of rapidly circulating water by 5°F to 10°F. Operating in the lower temperature range, of 70°F to 90°F, and in a higher ambient temperature, their efficiency is generally higher than that of conventional medium-temperature flat-plate collectors. Several manufacturers have discussed use of these collectors for aqua-culture and low-temperature industrial process applications.

The third category of collectors has been given the generic name of "special." These include evacuated-tube collectors and concentrating collectors. They are used for the same general purposes as conventional flat-plate collectors; that is for pool heating, domestic water heating, space heating and space cooling. The chief advantage of special collectors is that they have reduced heat losses and therefore can be used for high temperature applications. Both evacuated-tube and concentrating collectors achieve this higher efficiency through improved features of their construction that differ considerably from the more typical flat-plate collector.

C. Manufacturing Activity

1. Medium-temperature and special collector production: Total production of medium-temperature and special collectors for the second half of 1976 was 73% greater than that for the first half of the year. Production for the entire year was 168% greater than for 1975. For the July through December period of 1976, 1,220,331 sq ft of collectors were produced compared with 704,399 sq ft for the January through June period. Medium-temperature collector production amounted to 1,083,852 sq ft during the second half of the year, an increase of 65% over the 655,245 sq ft produced during the first 6 months. Special collector production in that same period jumped from 49,154 to 136,479 sq ft, an increase of 178% (see Table A-1 and Figure A-1).

A total of 164 firms manufactured medium-temperature collectors during this 6-month period and 14 manufactured special collectors. One of the latter also manufactured medium-temperature collectors, so that a total of 177 firms were manufacturing medium-temperature and special collectors. (This number compares with 142 firms that were manufacturing these types of collectors during the first half of 1976.) The 177 firms can be divided into two categories: 116 companies that were in production during the January through June period and 61 companies that produced for the first time or resumed production. Of the first group, 77 increased production, 34 decreased production and 5 reported no change. Twenty-six companies that were in the last survey did not report production; of these, 4 could not be located, 1 would not report production, 2 were absorbed into other solar energy companies, 1 left the solar business completely and the remaining 18 are either installing collectors or redesigning their collectors with the intention of manufacturing at some future date.

Collectors can also be categorized by the working medium. The 136,479 sq ft of special collector all used a liquid working medium. Of the medium-temperature collector manufacturers, 26 companies produced 173,069 sq ft of air collectors and 142 companies produced 910,783 sq ft of liquid collectors. Four companies produced both air and liquid collectors (see Table A-2).

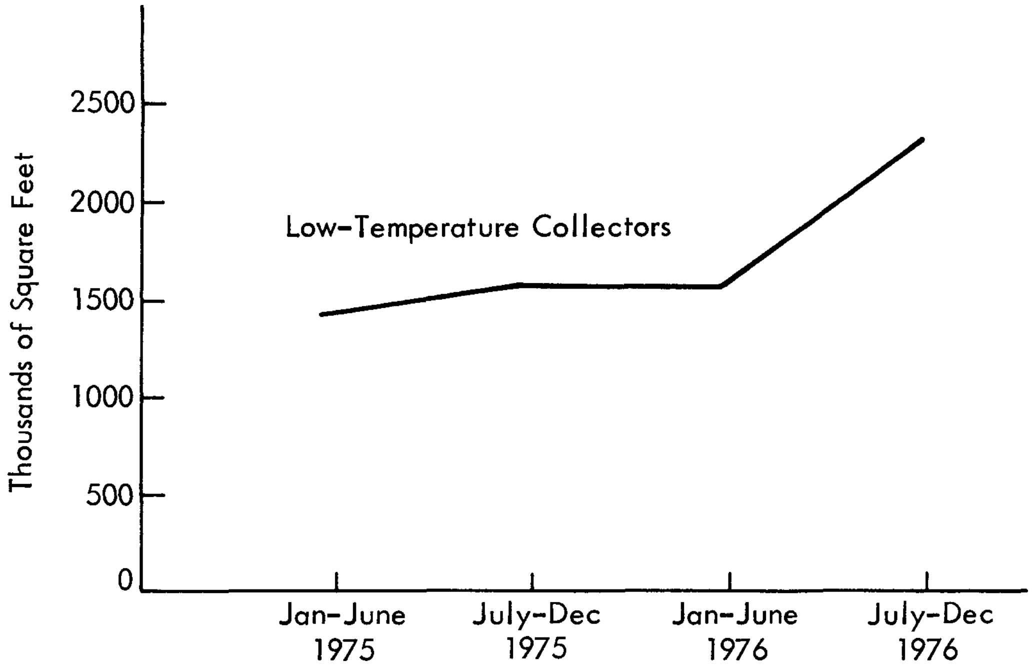
Comparison of production figures from this half-year with those of the previous half-year indicates that the industry is slowly becoming less volatile. New producers make up only 34% of the total number of companies compared to almost 50% 6 months earlier, and only 18% of the companies stopped production compared to 28% in the previous survey report. But 18% of the companies in an industry stopping production in a 6-month period still marks an industry that is far from stable. However, of the 58 companies that reported production rates of greater than 10,000 sq ft/year, only 9 (15%) are "new," 41 (71%) report increased production, and 8 (14%) decreased production. In the last survey the respective figures were 23% "new," 66% increased production, and 10% decreased production. The larger producers are retaining their relatively high degree of stability.

TABLE A-1

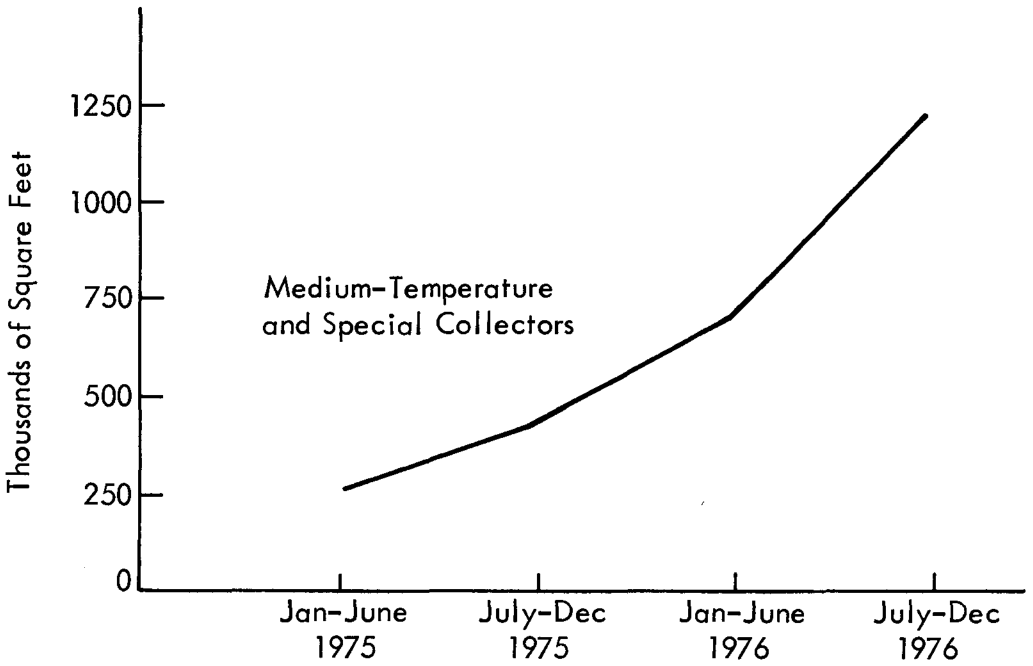
SOLAR COLLECTOR MANUFACTURING ACTIVITY - 1975 AND 1976

Solar Collector Annual Production Rate (square feet)	Total 1975			Semiannual 1976: January - June			Semiannual 1976: July - December			Total 1976		
	Number of Manufacturers	Square Feet	Percent	Number of Manufacturers	Square Feet	Percent	Number of Manufacturers	Square Feet	Percent	Number of Manufacturers	Square Feet	Percent
Medium Temperature & Special Collectors												
Greater than 50,000		*	*	5	218,000	30.9	12	543,437	44.5	9	692,204	36.0
10,000 - 50,000		*	*	25	287,310	40.8	46	504,137	41.3	38	829,465	43.1
Greater than 10,000	19	524,873	73.2	(30)**	(505,310)**	(71.7)**	(58)**	(1,047,574)**	(85.8)**	(47)**	(1,521,669)**	(79.1)**
2,000 - 10,000	35	149,097	20.8	65	175,464	24.9	68	150,550	12.3	76	333,752	17.3
1,000 - 1,999	14	19,969	2.8	20	15,175	2.2	22	14,237	1.2	33	44,615	2.3
Less than 1,000	50	23,321	3.2	27	8,450	1.2	29	7,970	0.7	47	24,694	1.3
Total	118	717,260	100.0	142	704,399	100.0	177	1,220,331	100.0	203	1,924,730	100.0
Special Collectors (included above)				(14)	(49,154)[R]	(7.0)	(14)	(136,479)	(11.2)	(18)	(185,633)	(9.6)
Low Temperature***	13	3,025,956		14	1,568,771		15	2,307,037	19	19	3,875,808	

* Not shown separately before 1976.
** Number total of two proceeding numbers in same column but not added for final total.
*** Low temperature collectors are shown separately because they are generally made of plastic or rubber and are used almost exclusively for applications below 100°F.
R = Revised
Source: FEA Collector Survey, April 1977.



Note: 1974 annual production was 1,137.2 thousands of square feet.



Note: 1974 annual production was 136.5 thousands of square feet.

Source: FEA Collector Survey, April 1977.

Figure A-1 - Solar Collector Semiannual Production

TABLE A-2

SOLAR COLLECTORS MANUFACTURED BY TYPE, AREA, AND NUMBER OF MANUFACTURERS, JULY - DECEMBER 1976

Type of Collectors	Area Manufactured (square feet)	Number of Manufacturers*
Medium-Temperature, liquid	910,783	142
Medium-Temperature, air	173,069	26
Special Collector	136,479	14
Total	1,220,331	
Low-Temperature, liquid	2,307,037	15

Breakdown of Number of Manufacturer by Types of Collectors Produced

Medium Temperature, liquid	132
Medium Temperature, air	22
Special Collector, liquid	12
Low Temperature, liquid	9
Medium Temperature, liquid & air	4
Medium Temperature & Special, liquid	1
Medium & Low Temperature, liquid	5
Special & Low Temperature, liquid	1
Total	186

* Note that these numbers are not additive.
Source: FEA Collector Survey, April 1977.

Another way of looking at the growth of the industry is to look at the number of producing companies and calculate the average production per company during each reporting period. Table A-3 shows this data. The number of companies has grown from 39 in 1974 to 177 in the last half of 1976, which is an average increase of 35 companies every 6 months with actual growth very close to this average. The average production over the same period has grown from 3,501 sq ft/company in 1974 to 6,895 sq ft/company in the last half of 1976, an average increase of 848 sq ft/company for each reporting period. However, in this instance the growth was below average for the first three half-years, but well above average for the last half-year. These figures indicate that the industry is still broadening and that overall growth has just spurted. This series of indicators should be very interesting to follow over the next several years.

2. Low-temperature collector production: During the last half of 1976 the production of low-temperature collectors, at 2,307,037 sq ft, was 47% greater than production during the first half of the year. Total production for the year, at 3,875,808 sq ft, was 28% greater than that for 1975. Fifteen companies manufactured low-temperature collectors, one more than during the previous 6 months; six of them report production and sales greater than 100,000 sq ft for this period. Of the 15 producing companies, 6 reported increased production, 4 decreased production, and the remaining 5 did not report production during the previous survey period. Figure A-1 shows that, after three 6-month periods of almost steady production, low-temperature collector production is climbing.

D. Applications of Solar Collectors

In the process of making previous surveys it was learned that many medium-temperature collectors are used for pool heating. During this survey specific questions were asked concerning collector applications. However, definitive data were available only when the manufacturers were directly involved in the installation of the collectors. Large manufacturers that used several distributors generally could not answer this question with accuracy. However, they were asked to make an estimate of the applications of their collectors, with suggested applications tailored to the type of collector. Table A-4 presents a summary of the analysis of these responses concerning the collector applications for this survey period. Based on these findings, the following simplified distribution is assumed for purposes of calculating fossil fuel replacement:

Pool Heating: 100% of low-temperature collectors, 17% of medium-temperature collectors, and 5% of special collectors (total, 2,498,116 sq ft of collector).

Domestic Hot Water: 39% of medium-temperature collectors and 65% of special collectors (total, 511,413 sq ft of collectors).

TABLE A-3

AVERAGE SQUARE FEET OF COLLECTOR SOLD PER COMPANY BY SEMIANNUAL PERIOD (Medium-Temperature and Special Collectors)

Period	Number of Manufacturers	Square Feet	Average Square Feet Per Company
1974 (Full Year Data)	39	136,540	3501
January-June 1975	69	276,466	4006
July-December 1975	102	440,794	4322
January-June 1976	142	704,399	4961
July-December 1976	177	1,220,331	6894

TABLE A-4

SOLAR COLLECTOR APPLICATIONS JULY - DECEMBER 1976

		Percentage of Application			
Type of Collector	Production (square feet)	Pool Heating	Domestic Hot Water	Space Heating	Space Cooling
Medium Temperature, liquid	910,783	20	46	32	2
Medium Temperature, air	173,069	--	6	94	--
Special Collectors, liquid	136,479	5	65	20	10
Low Temperature	2,307,037	100	--	--	--

Source: FEA Collector Survey, April 1977.

Space Heating and Hot Water: 42% of medium-temperature collectors and 20% of special collectors (total, 482,514 sq ft of collectors).

Space Cooling, Space Heating and Hot Water: 2% of medium-temperature collectors and 10% of special collectors (total, 35,325 sq ft of collectors).

E. Fossil Fuel Replacement

Using a solar energy computer program, FCHART, developed at the Solar Energy Center, University of Wisconsin, estimates of the annual solar system efficiency have been calculated.* For both domestic hot water systems and combined space heating and hot water systems, the annual solar system efficiency decreases as the solar portion of the thermal load increases. At the point where solar energy is supplying 50% of the thermal load, solar system efficiency is about 41% for domestic hot water systems and 25% for combined space heating and hot water systems.

FCHART is not applicable to either swimming pool systems or space cooling systems. On the basis of their operating characteristics it has been assumed here that pool application efficiency is 60% and that combined space-cooling, space-heating and hot water-heating systems have an efficiency of 40%.**

Using these figures, the Btu saved and the equivalent quantity of fuel oil can be calculated. For domestic hot water:

Average Daily Insolation	1,400 Btu/sq ft/day
Collector Area	511,413 sq ft
Annual Efficiency	0.41
Number of Days	365
Useful Thermal Energy	107.1×10^9 Btu/year
Useful Thermal Energy***	18,473 bbl oil/year
Useful Thermal Energy	50.6 bbl oil/day

For combined space heating and domestic hot water systems:

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* Solar system efficiency is defined here as that part of the annual total thermal load supplied by solar energy divided by the annual total solar energy falling on the collector.

** The FEA would appreciate obtaining information from anyone that has a methodology for calculating these solar system efficiencies.

*** Conversion factor: 5.8×10^6 Btu - 1 bbl of oil.

Average Daily Insolation	1,400 Btu/sq ft/day
Collector Area	482,514 sq ft
Annual Efficiency	0.25
Number of Days	365
Useful Thermal Energy	61.6×10^9 Btu/year
Useful Thermal Energy*	10,628 bbl oil/year
Useful Thermal Energy	29.1 bbl oil/day

For space cooling, space heating and hot water:

Average Daily Insolation	1,400 Btu/sq ft/day
Collector Area	35,325 sq ft
Annual Efficiency	0.40
Number of Days	365
Useful Thermal Energy	7.22×10^9 Btu/year
Useful Thermal Energy*	1,245 bbl oil/year
Useful Thermal Energy	3.4 bbl oil/day

The total useful thermal energy from solar hot water; hot water and space heating; and hot water, space heating, and space cooling is 175.9×10^9 Btu/year or 30,346 barrels of oil per year equivalent or 83.1 barrels of oil per day. If the collector were to replace electric resistance heating for the hot water and space heating and the equivalent of electric power cooling systems, the savings would be three times as great or 249.3 barrels of oil per day, since overall electric efficiency (including generation at the power plant) is about 33%.

Pool heating is assumed to have a collector usage of 1-1/2 months both before and after the normal swimming season, from mid-April through the end of May and from the early September through the middle of October.

For pool heating:

Average Insolation (for above period)	1,500 Btu/sq ft/day
Installation Angle Gain	1.12 (latitude minus 10°)
Collector Area	2.498×10^6 sq ft
Efficiency	0.60
Number of Days	90
Useful Thermal Energy	226.6×10^9 Btu/year
Equivalent Barrels of oil*	39,072 bbl oil/year
Equivalent Barrels of oil	107 bbl oil/day

* Conversion Factor: 5.8×10^6 Btu - 1 bbl of oil.

Since pool heating is usually done with natural gas at an efficiency of about 0.5, solar pool heating saves the equivalent of about 214 barrels of oil per day.

If the total reported production of solar collectors from 1974 through December 1976 is used (2.59 million sq ft of medium-temperature collector, 0.19 million sq ft of special collector, and 8.04 million sq ft of low-temperature collector), then the total current savings (including power plant conversion efficiency) from the assumed distribution of collectors would be about 560 barrels of oil per day for hot water, space heating and space cooling systems, and about 728 barrels per day for swimming pool heating and other low-temperature applications.

II. MANUFACTURERS OF SOLAR ENERGY COLLECTORS JULY - DECEMBER, 1976

1. A-1 Prototype
1288 Fayette
M,L El Cajon, California 92020
714/449-6726 (Mr. Mike Nicoletti)

2. Acorn Structures, Inc.
P.O. Box 250
M,L Concord, Massachusetts 01742
617/369-4111 (Mr. Bemis)

3. Acurex Corp./Aero Therm Division
485 Clyde Avenue
S,L Mountain View, California 94042
415/964-3200 (Mr. Jorgen Vindum)

4. Advance Cooler Manufacturing Corp.
Route 146, Bradford Industrial Park
M,L Clifton Park, New York 12065
518/371-2140 (Mr. Ed. O'Hanlon)

5. Aerocell Pollution Control, Inc.
Route 4, Box 386 B
M,L Tallahasse, Florida 32304
904/576-6611 (Mr. Al Culbertson)

6. Albuquerque Western Industries, Inc.
612 Commanche, N.E.
S,L Albuquerque, New Mexico 87107
505/344-7224 (Mr. T. L. White, Pres.)

7. Alcoa
1501 Alcoa Blvd.
L,L Pittsburgh, Pennsylvania 15219
412/553-3185 (Mr. William M. Foster)

8. All Sunpower, Inc.
10400 S.W. 187th Street
M,L Miami, Florida 33157
305/233-2224 (Mr. Leon Skinner)

9. Alten Associates, Inc.
2594 Leghorn Street
M,L Mountain View, California 94043
415/969-6474 (Mr. Barry Scott)

10. Amcon, Inc.
211 W. Willow Street
M,A Carbondale, Illinois 62901
618/457-3022 (Mr. Steve Miller)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

11\. American Helio Thermal Corp.
2625 S. Santa Fe, D1
M,L Denver, Colorado 80223
303/778-6050 (Mr. Bill Phillips)

12\. American Solar Heat Corp.
7 National Place
M,L Danbury, Connecticut 06810
203/792-0077 (Mr. Joseph Heyman)

13\. American Solar King Corp.
6801 New McGregor Highway
M,L Waco, Texas 76710
817/776-3860 (Mr. Brian Pardow)

14\. American Solar Power, Inc.
5018 West Grace Street
M,L Tampa, Florida 33607
813/251-6946 (Mr. Emil Chayet)

15\. American Sun Industries
3477 Old Conejo Rd. - P.O. Box 263
M,L Newbury Park, California 91320
805/498-9700 (Mr. Ken Vodraska)

16\. Ametek, Inc. Power Sys. Group
1 Spring Avenue
M,L Hatfield, Pennsylvania 19440
215/822-2971 (Mr. John Bowen)

17\. Aqua Solar
1232 Zacchini Avenue
L,L Sarasota, Florida 33577
813/958-5660 (Mr. Jerry Zella)

18\. Arizona Engineering & Refrigeration
635 W. Commerce Avenue
M,L Gilbert, Arizona 85234
602/892-9050 (Mr. Richard Mathwig)

19\. Associate Services
5105 72nd Avenue
M,L Hyattsville, Maryland 20784
301/459-6022 (Mr. William Stapler)

20\. Astron Solar Industries
465 McCormick Street
M,L San Leandro, California 94577
415/632-5400 (Mr. R. Bruce Springer)

21\. Atlas Vinyl Products
7002 Beaver Dam Road
L,L Levittown, Pennsylvania 19057
215/946-3620 (Mr. M. A. Gruettner)

22\. Beutels Solar Heating Company
7161 N.W. 74th Street
M,L Miami, Florida 33166
305/885-0122 (Mr. Lindstrom)

23\. Burke Industries, Inc.
2250 South 10th Street
L,L San Jose, California 95112
408/297-3500 (Mr. Larry Schader)

24\. Business & Technology, Inc.
2800 Upton Street, N.W.
M,L Washington, D.C. 20008
202/362-5991 (Mr. Stephen Molivadas)

25\. Calmac Manufacturing Corp.
P.O. Box 710
M,L Englewood, New Jersey 07631
201/569-0420 (Mr. Calvin MacCracken)

26\. Capital Solar Heating, Inc.
376 N.W. 25th Street
M,L Miami, Florida 33127
305/576-2380 (Mr. Jack Saifman)

27\. Chamberlain Manufacturing Corp.
845 Larch Avenue
M,L Elmhurst, Illinois 60126
312/279-3600 (Mr. Charles Franke)

28\. Champion Home Builders Co.
5573 E. North Street
M,A Dreyden, Michigan 48428
313/796-2111 (Mr. Henry Leck)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

29. Chemical Processors, Inc.
P.O. Box 10636
M,L St. Petersburg, Florida 33733
813/822-3689 (Mr. John J. Hicks)

30. Cole Solar Systems, Inc.
440-A East St. Elmo Rd.
M,L Austin, Texas 78745
512/444-2565 (Mr. Warren Cole)

31. Columbia Solar Energy Division
55 High Street
M,L Holbrook, Massachusetts 02343
617/767-0513 (Mr. Walter Barrett)

32. Consumer Energy Corporation
4234 S.W. 75th Street
M,L Miami, Florida 33155
305/266-0124 (Mr. Wm. Weitzman)

33. Contemporary Systems, Inc.
68 Charlonne Street
M,A Jaffrey, New Hampshire 03452
603/532-7972 (Mr. J. Christopher)

34. Crimsco, Inc.
5001 East 59th Street
M,A Kansas City, Missouri 64130
816/333-2100 (Mr. Keith Solomon)

35. CSI Solar Systems Division
12400 49th Street
M,L Clearwater, Florida 33520
813/577-4228 (Mr. Roy Sallen)

36. D. W. Browning Contracting Co.
475 Carswell Avenue
M,L Holly Hill, Florida 32017
904/252-1528 (Mr. Ike Johnston)

37. Daystar Corporation
41 Second Avenue
M,L Burlington, Massachusetts 01803
617/272-8460 (Mr. Richard Cummings)

38. Design Sciences -
Jacobs Engineering Center
251 S. Lake Avenue
S,L Pasadena, California 91101
213/681-4561 (Mr. Bernard Eldridge)

39. Dick Mills/Airtron Inc.
15286 U.S. Highway S.
M,L Clearwater, Florida 33516
813/531-3581 (Mr. Bob Morgan)

40. E&K Service Company
16824 74th Avenue N.E.
M,L Bothell, Washington 98011
206/486-6660 (Mr. James Eubank)

41. El Camino Solar Systems
5330 Debbie Lane
M,L Santa Barbara, California 93111
805/964-8676 (Mr. T. C. Honikman)

42. Energy Converters, Inc.
2501 N. Orchard Knob Avenue
M,L Chattanooga, Tennessee 37406
615/624-2608 (Mr. Barry Rhodes)

43. Energy Dynamics Corporation
6062 E. 49th Avenue
M,L Commerce City, Colorado 80022
303/321-3314 (Ms. Sherry Lynch)

44. Energy Systems, Inc.
634 Crest Drive
M,L El Cajon, California 92021
714/447-1000 (Mr. Terrence Caster)

45. Enviropane, Inc.
350 N. Marshall Street
M,L Lancaster, Pennsylvania 17602
717/299-3737 (Mr. M. Bond, V.P.)

46. ERA DEL SOL
5960 Mandarin Avenue
M,L Goleta, California 93017
805/967-2116 (Mr. E. A. Anderson)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

47. Evand Precision, Inc.
320 Locust Street
M,L Lancaster, Ohio 43130
614/654-2196 (Mr. Richard Evans)

48. FAFCO
235 Constitution Drive
L,L Menlo Park, California 94025
415/321-3650 (Mr. Freeman Ford)

49. Falbel Energy Systems Corp.
P.O. Box 6
S,L Greenwich, Connecticut 06830
302/357-0626 (Mr. James S. Love)

50. Flagala Corporation
9700 W. Highway 98
M,L Panama City, Florida 32401
904/234-6559 (Mr. Swicord)

51. Florida Solar Power, Inc.
1327 South Monroe St. - P.O. Box 5846
M,L Tallahasse, Florida 32301
904/224-8270 (Mr. Wm. Malloy)

52. General Atomic Co.
P.O. Box 81608
S,L San Diego, California 92138
814/455-2090 (Mr. John Schuster)

53. General Electric Company
P.O. Box #8661/Bldg. #7
M,L Philadelphia, Pennsylvania 19101
215/962-4785 (Mr. Moore)

54. General Energy Devices
P.O. Box 5679
M,L Clearwater, Florida 33518
813/586-3585 (Mr. Dorman)

55. Gramer Industries
5441 E. Nassau Circle
M,L Englewood, Colorado 80110
303/753-1427 (Mr. Gramer)

56. Grumman Aerospace Corporation
Energy Programs, Plant 25
M,L Bethpage, New York 11779
516/575-6205 (Mr. Ken Speiser)

57. Gulf Thermal Corporation
2215 Industrial Blvd.
M,L P.O. Box 13124 Air Gate Branch
Sarasota, Florida 33578
813/355-9783 (Mr. Dudley Slocum)

58. Halstead Industries
P.O. Box 1110
M,L Scottsboro, Alabama 35768
205/259-1212 (Mr. Otto Nussbaum)

59. Hansberger Refrigeration & Electric Co.
2450 8th Street
M,L Yuma, Arizona 85364
602/783-3331 (Mr. Ed. Hansberger)

60. Helio Dynamics
518 South Van Ness Avenue
M,L Los Angeles, California 90020
213/384-9853 (Mr. Truman Temple)

61. Helio Thermics, Inc.
10 Delores Street
M,A Greenville, South Carolina 29605
803/277-6581 (Mr. Bill Haas)

62. Helios Corporation
1313 Belleview Avenue
M,L Charlottesville, Virginia 22901
804/293-9574 (Mr. John M. Embree)

63. Heliotherm, Inc.
West Lenni Road
M,L Lenni, Pennsylvania 19052
215/459-9030 (Mr. Don Kirkpatrick)

64. Hexcel Corporation
11711 Dublin Blvd.
S,L Dublin, California 94566
415/828-4200 (Mr. Robert Hull)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

65. Industrial Erectors, Inc.
21877 Euclid Avenue
M,A Cleveland, Ohio 44117
216/531-3890 (Mr. Leonard Lowe)

66. International Environment Corp.
129 Halstead Avenue
M,L Mamaroneck, New York 10543
914/698-8130 (Mr. R. Rothschild)

67. Isle Engineering, Inc.
7177 Arrowhead Road
M,L Duluth, Minnesota 55811
218/729-6858 (Mr. John Isle)

68. J. S. Johnston Company
33458 Angeles Forest Hwy.
M,A Palmdale, California 93550
805/947-3791 (Mr. J. G. Johnston)

69. J. R. Simmons Construction Co.
2185 Sherrywood Drive
M,L S. Daytona, Florida 32021
904/677-5832 (Mr. Richard Simmons)

70. Kalwall Corporation
P.O. Box 237
M,A Manchester, New Hampshire 03105
603/668-8186 (Mr. Drew Gillett)

71. KTA Corporation
12300 Washington Avenue
M,L Rockville, Maryland 20852
301/468-2066 (Mr. Graves)

72. Largo Solar Systems, Inc.
2525 Key Largo Lane
M,L Fort Lauderdale, Florida 33312
305/583-8090 (Mr. R. T. Hannivig)

73. Lennox Industries, Inc.
200 S. 12th Avenue
M,L Marshelltown, Iowa 50158
515/754-4011 (Mr. Norman Bernhardt)

74. Libby Owens Ford
Technology Center
M,L 1701 East Broadway
Toledo, Ohio 43605
419/247-4357 (Mr. Ron Goodman)

75. McArthurs, Inc.
P.O. Box 236
M,A Forest City, North Carolina 28043
M,L 704/245-7223 (Mr. W. H. McArthur)

76. Mid-Western Solar Systems, Inc.
2235 Irvin Cobb Drive
M,A Paducah, Kentucky 42001
502/443-6295 (Mr. Lee Molloy)

77. National Energy Company
21716 Kenrick Avenue
M,A Lakeville, Minnesota 55044
612/469-3401 (Mr. Gary Hoffman)

78. National Solar Supply
2331 Adams Drive N.W.
M,L Atlanta, Georgia 30318
404/352-3478 (Mr. Tom Stansell)

79. Natural Energy Systems
Marketing Arms Division
M,L 1654 Pioneer Way
El Cajon, California 92020
714/440-6411 (Mr. Don Haydon)

80. Northrup, Inc.
302 Nichols Drive
S,L Hutchins, Texas 75141
M,L 214/225-4291 (Mr. Lynn Northrup)

81. NRG, Ltd.
901 Second Avenue East
S,L Coralville, Iowa 52241
319/354-2033 (Mr. Craig Collison)

82. O.S. Solar Energy, Inc.
P.O. Box 221
M,L Milford, Ohio 45150
513/831-4879 (Mr. Hotic)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

83. Owens Illinois, Inc.
P.O. Box 1035
S,L Toledo, Ohio 43666
419/242-6543 (Mr. Richard Ford)

84. Payne, Inc.
1910 Forest Drive
M,L Annapolis, Maryland 21401
301/261-2325 (Mr. P. R. Payne)

85. Pet-Craft Assemblies, Solar Div.
430 Dayton Blvd.
M,L Melbourne Village, Florida 32901
305/724-1393 (Mr. Jack C. Houck)

86. Piper Hydro Corporation
2895 East La Palma
M,L Anaheim, California 92806
714/630-4040 (Mr. Joe Grenader)

87. Pleiad-Industries, Inc.
Springdale Road
M,L West Branch, Iowa 52358
319/356-2735 (Mr. Donald Laughlin)

88. Powell Brothers, Inc.
5903 Firestone Blvd.
M,L South Gate, California 90280
213/869-3307 (Mr. Hayward Powell)

89. PPG Industries
One Gateway Center
M,L Pittsburgh, Pennsylvania 15222
412/434-3552 (Mr. Barker)

90. R.M. Products
5010 Cook Street
M,L Denver, Colorado 80216
303/825-0203 (Mr. Don Erickson)

91. RAYPAK, Inc.
3111 Agoura Road
M,L Westlake Village, California 91361
L,L 213/889-1500 (Mr. Hugo Byers)

92. Revere Copper & Brass, Inc.
P.O. Box 151
M,L Rome, New York 13440
315/338-2295 (Mr. William Heidrick)

93. Reynolds Metal Company
6601 West Broad Street
M,L Richmond, Virginia 23261
804/281-3026 (Mr. Chester Holtyn)

94. S.W. Ern-Tech, Inc.
3030 S. Valley View Blvd.
M,L Las Vegas, Nevada 89102
702.873-1975 (Mr. Gary Halverson)

95. SEMCO
1091 S.W. 1st Way
M,L Deerfield Beach, Florida 33441
305/427-0040 (Mr. David Aspinwall)

96. Sheldahl Company
Highway 3 North
S,L Northfield, Minnesota 55057
612/469-3471 (Mr. Jim Menke)

97. Simons Solar & Environmental Sys. Inc.
24 Carlisle Pike
M,L Mechanicsburg, Pennsylvania 17055
717/697-2778 (Mr. Earl Simons)

98. Solamatic
2413 Garden Street
M,L Tampa, Florida 33605
813/689-1182 (Mr. Barlow, Sr.)

99. Solar-Aire of California
82 S. Third Street
M,A San Jose, California 95113
408/295-2528 (Mr. J. C. Amaral)

100. Solar II Interprises
19675 Skyline Blvd.
M,L Los Gatos, California 95030
408/354-3353 (Mr. Michael Clifton)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

101. Solar American
P.O. Box 7239
M,L Hampton, Virginia 23666
804/874-0836 (Mr. R. J. Pegg)

102. Solar Applications, Inc.
7926 Convoy Ct.
M,L San Diego, California 92111
714/292-1857 (Mr. Ric Sorenson)

103. Solar Central
7213 Ridge Road
M,L Mechanicsburg, Ohio 43044
513/828-1350 (Mr. D. Greider)

104. Solar Comfort Systems
Suite 606, 4853 Cordell Avenue
M,L Bethesda, Maryland 20014
301/652-8941 (Mr. David DeRiemer)

105. Solar Corporation of America
19 Winchester Street
M,L Warrenton, Virginia 22816
703/347-0550 (Mr. Walter Sutton)

106. Solar Development, Inc.
4180 West Roads Drive
M,L West Palm Beach, Florida 33407
M,A 305/842-8935 (Mr. Don Kazimir)

107. Solar Dynamics, Inc.
4527 E. 11th Avenue
M,L Hialeah, Florida 33013
305/688-4393 (Mr. Ed Chester)

108. Solar Energy Company
Deerwood Drive
L,L Merrimack, New Hampshire 03054
603/424-5168 (Mr. Roger Papineau)

109. Solar Energy Components, Inc.
1605 North Cocoa Blvd.
M,L Cocoa, Florida 32922
305/632-2880 (Mr. Aulton A. Autry)

110. Solar Energy Contractors
3156 Leon Road - P.O. Box 16425
M,L Jacksonville, Florida 32216
904/641-5611 (Mr. Wallace Stewart)

111. Solar Energy Products Company
121 Miller Road
M,A Avon Lake, Ohio 44012
216/933-5000 (Mr. Frank Rom)

112. Solar Energy Resources Corporation
10639 S.W. 185 Terrace
M,L Miami, Florida 33157
305/233-0711 (Mr. Balmer)

113. Solar Energy Systems
330 LeFitte Ct.
M,L Merritt Island, Florida 32952
305/452-2628 (Mr. Roy Meabe)

114. Solar Energy Systems, Inc.
2492 Banyan Drive
L,L Los Angeles, California 90049
M,L 213/472-6508 (Dr. Kenneth Brody)

115. Solar Energy Systems, Inc.
1 Olney Ave., Cherry Hill Industrial Pk.
M,L Cherry Hill, New Jersey 08003
609/424-4446 (Mr. Nathan Brussels)

116. Solar Engineering, Inc.
P.O. Box 1358
M.L Boca Raton, Florida 33432
305/368-2456 (Mr. Ed Gonzales)

117. Solar-Eye Products, Inc.
1300 N.W. McNabb Road
L,L Fort Lauderdale, Florida 33309
M,L 305/974-2500 (Mr. Wallace Starr)

118. Solar Fin Systems
140 S. Dixie Highway
M,L St. Augustine, Florida 32084
904/824-3522 (Mr. Webster Felix)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

119. Solar Heat Company
P.O. Box 110
M,A Greenville, Pennsylvania 16125
412/588-5650 (Mr. Alton F. Oakes)

120. Solar Heat Corporation
1252 French Avenue
M,L Lakewood, Ohio 44107
216/228-2993 (Mr. Tom Linder)

121. Solar Heating & Air Condition Sys.
13584 49th Street North
M,L Clearwater, Florida 33520
813/577-3961 (Mr. Breckenridge)

122. Solar Homes Inc.
2 Narragansett Avenue
M,A Jamestown, Rhode Island 02835
401/423-1025 (Mr. Dickenson)

123. Solar Inc.
P.O. Box 246
M,A Mead, Nebraska 68041
402/624-6611 (Mr. Chuck Higgin)

124. Solar Industries of Florida
3231 Trot River Blvd. - P.O. Box 9013
M,L Jacksonville, Florida 32216
904/768-4323 (Mr. Laird)

125. Solar Innovations
412 Longfellow Blvd.
M,L Lakeland, Florida 33801
813/688-8373 (Mr. Ron Yachabach)

126. Solar Kinetics Corporation
P.O. Box 17308
S,L West Hartford, Connecticut 06117
203/233-4461 (Mr. James Pohlman)

127. Solar Manufacturing Company
Conneaut Lake Road
M,A Greenville, Pennsylvania 16125
412/588-2571 (Mr. Jake McClelland)

128. Solar One Ltd.
709 Birdneck Road
M,L Virginia Beach, Virgnina 23451
804/422-3262 (Mr. Dennis Ackerman)

129. Solar Pool Heaters of SW Florida
901 S.E. 13th Place
L,L Cape Coral, Florida 33904
813/542-1500 (Mr. Ward Morrisey)

130. Solar Products Manufacturing Corp
151 John Downey Drive
M,L New Britain, Connecticut 06051
203/224-2164 (Mr. Alvin Trumball)

131. Solar Products, Sun-Tank, Inc.
614 N.W. 62nd Street
M,L Miami, Florida 33150
305/756-7609 (Mr. Houtkin)

132. Solar Research Div./Refrigeration Research
525 N. Fifth Street
M,L Brighten, Michigan 48116
313/227-1151 (Mr. Ed Bottum)

133. Solar Research Systems
Bldg. 1, Suite 105
3001 Red Hill Avenue
M,L Costa Mesa, California 92626
714/545-4941 (Dr. Joseph Farber)

134. Solar Shelter
P.O. Box 36
M,A Reading, Pennsylvania 19603
215/488-7624 (Mr. Schmauder, Sr.)

135. Solar Systems by Sundance
4815 S.W. 75 Avenue
M,L Miami, Florida 33155
305/264-1894 (Mr. Tom Martone)

136. Solar Systems, Inc.
507 W. Elm Street
S,L Tyler, Texas 75701
212/592-5243 (Mr. Estes)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

137. Solar Tech
8250 Vickers Street
L,L San Diego, California 92111
S,L 714/560-8434 (Burtha Reynolds)

138. Solar Technology, Inc.
3827 Oakcliff Industrial Ct.
M,L Atlanta, Georgia 30340
404/449-0900 (Mr. Nick Noland)

139. Solar Water Heaters of New Port Richey
1214 U.S. 19
M,L New Port Richey, Florida 33552
813/848-2343 (Mr. Bill Ramsey)

140. Solarator, Inc.
P.O. Box 277
L,L Madison Heights, Michigan 48071
313/642-9377 (Mr. E. Konopka)

141. Solaray, Inc.
324 S. Kidd Street
M,A Whitewater, Wisconsin 53190
414/473-2525 (Mr. R. Shrivseth)

142. Solaray, Inc.
P.O. Box 590
M,L Old Saybrook, Connecticut 06475
203/399-7112 (Mr. Wm. J. Vernon)

143. Solaracoa
4925 West Park Drive
M,L N. Hollywood, California 91601
213/426-7655 (Mr. Lieu Pham)

144. Solargenics
9713 Lurline Avenue
M,L Chatsworth, California 91311
213/998-9896 (Mr. David Collins)

145. Solargizer Corporation
220 Mulberry Street
M,L Stillwater, Minnesota 55802
612/739-0117 (Dr. P. Holmberg)

146. Solargy Inc.
70 Zoe Street
M,L San Francisco, California 94107
415/495-4303 (Mr. Ron Smith)

147. Solaron Corporation
300 Galleria Tower, 720 S. Colorado Blvd
M,A Denver, Colorado 80222
303/759-0101 (Mr. Shackelford)

148. Solarway
P.O. Box 217
M,L Redwood Valley, California 95470
707/485-7616 (Mr. Ben Piraino)

149. Sol Tex Corporation
1804 Afton Street - Lock Lane
M,L Houston, Texas 77055
713/782-4478 (Mr. Charles Chenault)

150. Solus, Inc.
P.O. Box 35227
M,L Houston, Texas 77035
713/772-6416 (Mr. Robert Barrett)

151. Southeastern Solar Systems
4705 J. Bakers Ferry Road
P.O. Box 44066
M,L Atlanta, Georgia 30336
404/691-1864 (Mr. Charles E. Moore)

152. Southern Lighting Mfg. Co.
501 Elwell Avenue
M,L Orlando, Florida 32803
305/894-8851 (Mr. Bill Ford)

153. Southwest Standard
P.O. Box 10094
M,L El Paso, Texas 79991
915/533-6291 (Mr. George Doyle)

154. Standard Electric Co.
P.O. Box 631
M,L Rocky Mount, North Carolina 27801
919/442-1155 (Mr. Lynell Bynum)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

155. State Industries, Inc.
Cumberland Street
M,L Ashland City, Tennessee 37015
615/792-4371 (Mr. Herb Lindahl)

156. Sun Century Systems
P.O. Box 2036
M,L Florence, Alabama 35630
205/764-0795 (Mr. Howard Craig)

157. Sun Earth, Solar Products Corp.
Progress Drive
M,L Montgomeryville, Pennsylvania 18936
215/699-7892 (Mr. H. Katz)

158. Sun Power Corporation
P.O. Box 16963
M,L Orlando, Florida 32811
305/876-2237 (Mr. C. J. McCommon)

159. Sun Stone
P.O. Box 941
M,A Sheboygan, Wisconsin 53081
414/452-8194 (Mr. Richard Linde)

160. Sun Systems of America, Inc.
P.O. Box 10336
M,L Jacksonville, Florida 32207
904/389-0493 (Mr. Truitt George)

161. Sun Systems, Inc.
P.O. Box 347
M,A Milton, Massachusetts 02186
M,L 617/265-9600 (Mr. Paul Hayes)

162. Sun-Light & Power
115 Park Place
M,L Point Richmond, California 03224
415/232-0277 (Mr. Lawrence Stern)

163. Sunburst Solar Energy, Inc.
P.O. Box 2799
L,L Menlo Park, California 94025
M,L 415/327-8022 (Mr. Larry Newton)

164. Sunpower Systems Corporation
2123 South Priest Road, Suite 216
S,L Tempe, Arizona 85252
602/968-7425 (Mr. William Matlock)

165. SunSav, Inc.
250 Canal Street
M,L Lawrence, Massachusetts 01840
617/459-3321 (Mr. Peter Ottmar)

166. Sunshine Utility Company
1444 Pioneer Way, Suite 9 & 10
M,L El Cajon, California 92020
714/440-3151 (Mr. J. M. Caldwell)

167. Suntap, Inc./Bross Utilities Service Co.
42 E. Dudley Town Road
M,L Bloomfield, Connecticut 06002
203/243-1781 (Mr. Theodore D. Bross)

168. Sunwall, Inc.
P.O. Box 9723
M,A Pittsburgh, Pennsylvania 15229
412/364-5349 (Mr. Gramm)

169. Sunworks Division/Enthone Co.
P.O. Box 1004
M,L New Haven, Connecticut 06508
M,A 203/934-6301 (Mr. Floyd Perry)

170. Systems Technology, Inc.
P.O. Box 337
M,L Shalimar, Florida 32579
904/863-9213 (Mr. Bill Cronk)

171. Temp-O-Matic Cooling Company
87 Luguer Street
M,L Brooklyn, New York 11231
212/624-5600 (Mr. A. Martinelli)

172. The Solaray Corporation
2414 Makiki Heights Drive
M,L Honolulu, Hawaii 96822
808/533-6464 (Mr. L. M. Judd)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid

173\. Tri-State-Solar King, Inc.
P.O. Box 503
M,L Adams, Oklahoma 73901
405/253-6562 (Mr. George Shaw)

174\. U.S. Solar Pillow
P.O. Box 987 - 416 East Oak
L,A Tucumcari, New Mexico 88401
505/461-2608 (Mr. Dick Carmack)

175\. Unit Electric Control, Inc.
130 Atlantic Drive
M,L Maitland, Florida 32751
305/831-1900 (Mr. Maurice Stewart)

176\. United States Solar Systems, Inc.
P.O. Box 48695
M,L Los Angeles, California 90048
L,L 213/851-2833 (Mr. A. F. Lombardo)

177\. Unitspan Architectural Sys., Inc.
9419 Mason Avenue
M,L Catsworth, California 91311
213/998-1131 (Mr. Abe Grossman)

178\. Universal Solar Energy Co.
1802 Madrid Avenue
M,L Lake Worth, Florida 33461
305/586-6020 (Mr. Frank Russell)

179\. W. R. Robbins & Sons
1401 N.W. 20th Street
M,L Miami, Florida 33142
305/325-0880 (Mr. W. R. Robbins)

180\. Wallace Sheet Metal Company
831 Dorsey Street
Gainsville, Georgia 30501
M,L 404/534-5971 (Mr. Joe Pendergrass)

181\. Western Energy, Inc.
454 Forest Avenue
M,L Palo Alto, California 94302
415/327-3371 (Mr. Norman Rees)

182\. Wilcon Corporation
3310 S.W. Seventh Street
M,L Ocala, Florida 32670
904/732-2550 (Mr. Ken Wilson)

183\. Wilcox Manufacturing Corp.
13375 U.S. 19 North
P.O. Box 455
M,L Pinellas Park, Florida 33565
813/531-7741 (Mr. Wilcox)

184\. Ying Manufacturing Corp.
1957 West 144th Street
M,L Gardena, California 90249
213/327-8399 (Mr. Ying Yu)

185\. Zomeworks Corporation
P.O. Box 712
M,L Albuquerque, New Mexico 87103
505/242-5354 (Mr. Peter Voorkees)

L,L = Low temperature, liquid
M,A = Medium temperature, air
M,L = Medium temperature, liquid
S,L = Special Collector, liquid
* Note: One company requested that their name be omitted from the list. They only manufacture collectors to install in houses they are building.

III. CURRENT AND FUTURE INDUSTRY STRUCTURE

This section provides a general description of the solar energy industry infrastructure.* Section A describes the solar collector industry, the organization of the construction industry, and the relationship of the solar industry to the building industry. Section B details the plant and financial requirements for a prototypical collector manufacturing facility. Future collector costs as a function of volume of production are projected in Sections C and D.

A. Solar Heating and Cooling Industry Infrastructure

1. The solar industry: The solar industry is comprised of over 200 firms. Their size varies from garage-shop types to relatively low level operations by a number of larger firms. The solar industry may be considered in terms of the following elements:

a. Raw materials: aluminum ingots, pig iron.
b. Semi-finished materials: flat sheet, billets.
c. Finished products: glass, roll bond absorber plates.
d. Collector manufacture.
e. Installation and maintenance.

The flow of the materials is also shown in Figure A-2.

Additionally, these segments are supported by a design and integration function.

An examination of the firms that make up the solar industry show some degree of vertical integration. In some cases, two levels of vertical integration are seen. Some of the larger firms are primarily in the business of supplying raw materials: Revere, copper; Reynolds, aluminum; P.P.G., glass; Alcoa, aluminum; and Owens-Illinois, glass. These firms are vertically integrated from one raw material to the finished collector assembly and have thus far elected not to participate in the total system design or installation. On the other hand, some of the smaller firms are vertically integrated from collector manufacture through distribution and installation.

Collector design is by no means fixed. There are almost as many different designs as there are manufacturers. Material requirements and plant requirements vary considerably from design to design.

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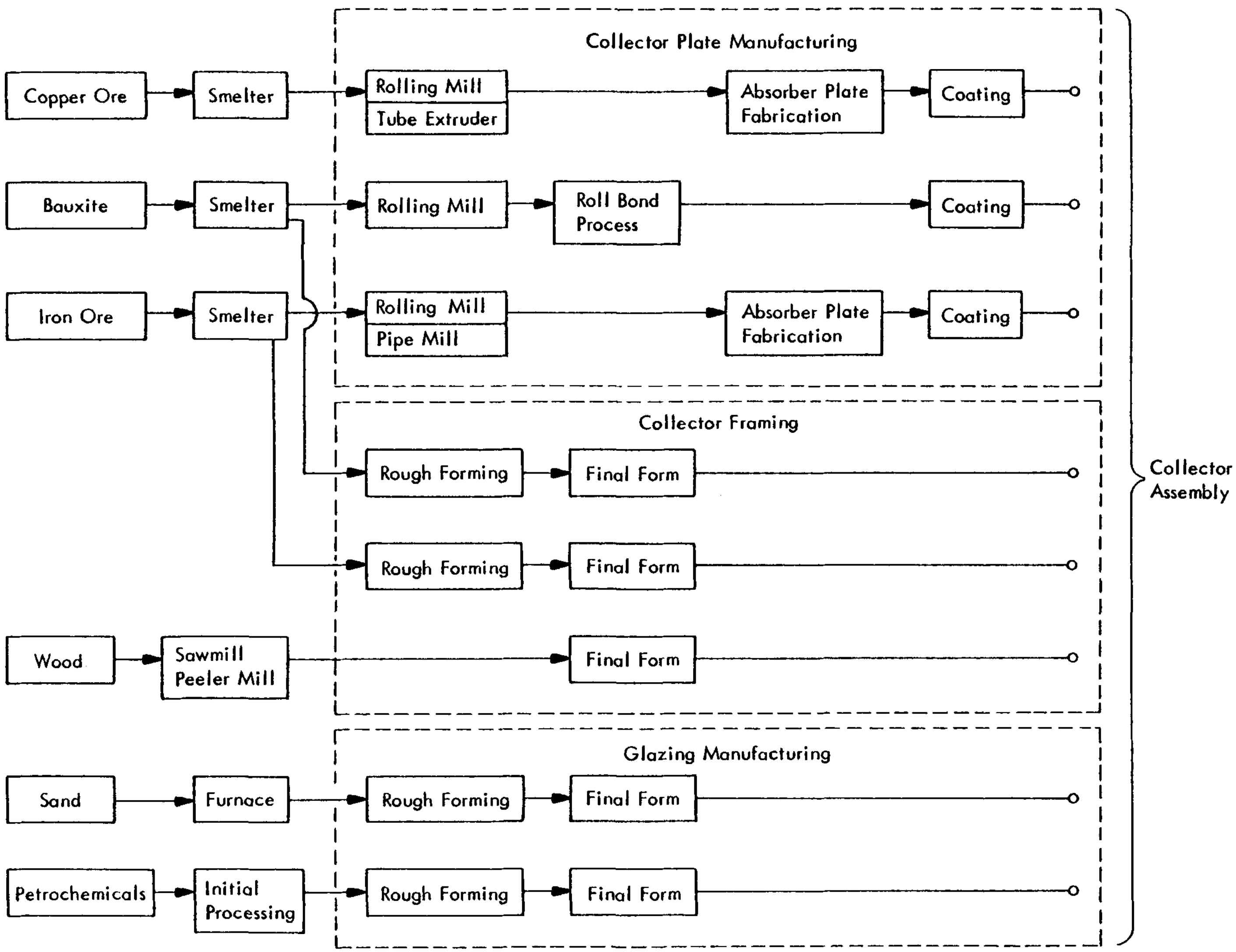
* This section is excerpted, with only minor modifications, from a previous study for FEA, Intertechnology Corporation (ITC), Industry-Market Infrastructure Analysis, Final Report to the Federal Energy Administration, Order No. P-05-76-2382-0, June 25, 1976.



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-2 - Process Flow Chart for Collector Manufacturing

The greater number of solar industry participants manufacture solar collectors or their components. As can be seen in Table A-5, more than 17% of the firms in this study, mostly small companies, provide complete solar systems. Many offer some service in engineering and design support, and nearly as many more are planning to add to this service. No maintenance service is indicated by the respondees.

The marketing efforts of the various firms appear to be directed at different buyers (see Table A-6). For the most part, the smaller manufacturers seem to be directing their marketing activities toward the individual homeowner, primarily the retrofit market. One of the more aggressive solar groups has created several manufacturing franchises as well as retail outlets. The larger manufacturers, in the sense of total firm size, are apparently focusing their primary solar effort toward selling components to mechanical engineers and architects, most of whom are not prepared to design, install, and maintain complete systems. But at least half of the companies which specified areas of distribution claim to be prepared to expand to nationwide distribution.

2. Current building-construction organization: The building and construction industry does not exhibit a uniform organization.1/ The solar industry must interface with the existing institutions to eliminate negativism in response to this innovation. A quick analysis of the building and construction industry shows that there are six markets to be considered within which the solar industry must fit. These are (1) new-commercial, (2) retrofit-commercial, (3) new-residential, (4) retrofit-residential, (5) new-industrial, and (6) retrofit-industrial. For the purposes of the discussion, only the first four cases will be examined.

The participants in the overall building and construction industry are: (1) architect; (2) mechanical consultant; (3) general contractor; (4) mechanical contractor; (5) HVAC contractor; and (6) plumbing contractor. In addition, there are the owner and the developer. The four cases of organizations are shown in Figures A-3 through A-6.

The fee schedule for the various participants consists of a sliding percentage scale, depending upon the size of the job for which the fee is calculated. The standard or typical fee schedules are shown in Table A-7.

1/ Schoen, R., A. S. Hirschberg, and J. M. Weingart, "New Energy Technologies for Buildings," Ballings Publishing Co., Cambridge, Mass., 1975.

TABLE A-5

PRODUCT LINES AND SERVICES OF SOLAR COMPANIES

No. of Firms	Assembly and Manufacture: Collector	Storage	Controls	Collector Components: Plate	Coating	Tubing	Glazing	Complete Systems	Design
Total 154	82	3	31	7	4	4	8	27	22
% Firms	53.2	1.9	20.1	4.5	2.6	2.6	6.2	17.5	14.3

	No. of Models	Installation: By Manufacturer	Instructions Available	Maintenance: Operation Manual	Warranty
Total	191	56	90	53	98
% Models		29.3	47.1	27.7	51.3

Source: Energy Research and Development Administration, Solar Energy Heating and Cooling Product, October 1975, Oak Ridge, Tennessee.

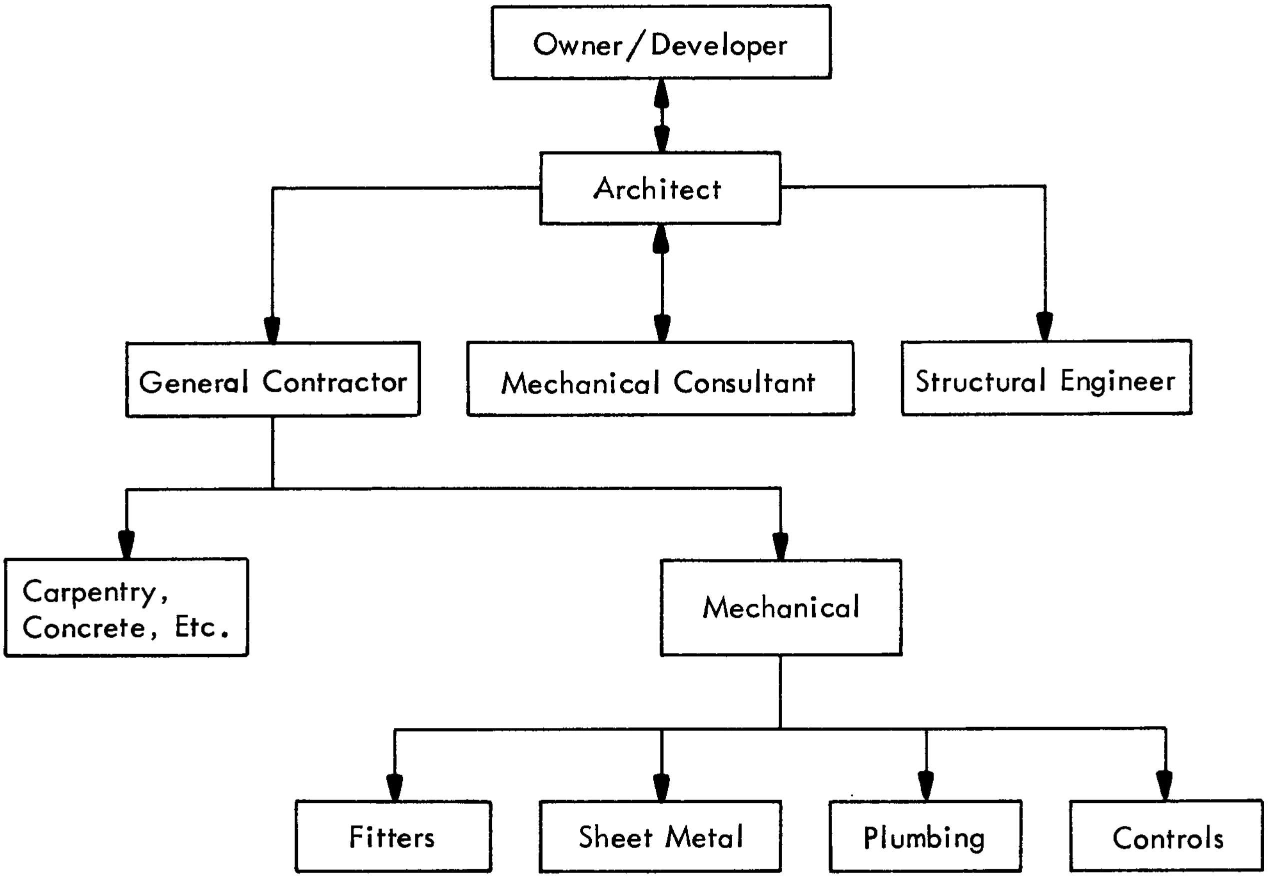
TABLE A-6

TARGET MARKET AND LOCATIONS

No. of Firms	Ultimate Customer						Distribution Region								
										Regions of USA					
	Arch.	HVAC	Devel.	Mech.	Manu.	Bldg. Owner	Home State	Inter-Nat'L	USA	NE	E	S	SW	E	NW
Total 104	4	60	1	67	28	22	26	7	52	4	1	4	5	2	3
% Total	3.8	57.7	0.96	64.4	26.9	21.2	25*	6.7	50	3.8	0.96	3.8	4.8	1.9	2.9

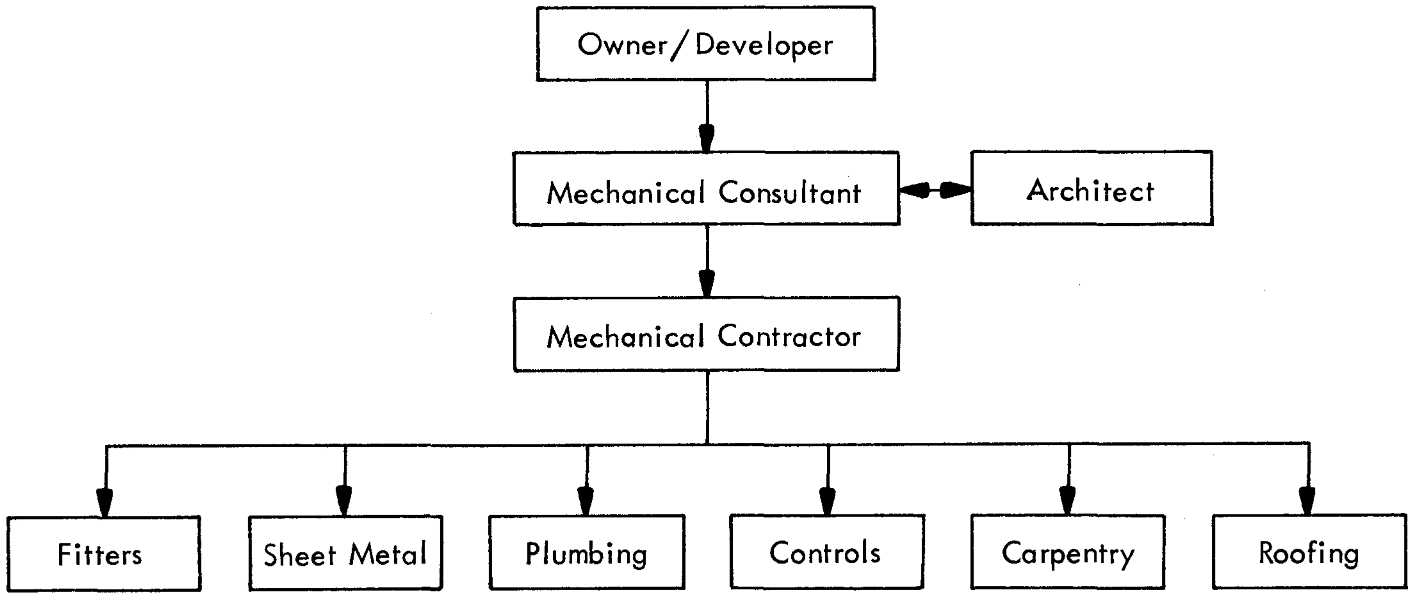
Source: Energy Research and Development Administration, Solar Energy Heating and Cooling Product, October 1975, Oak Ridge, Tennessee.

* When distribution region not identified, home state distribution was assumed.



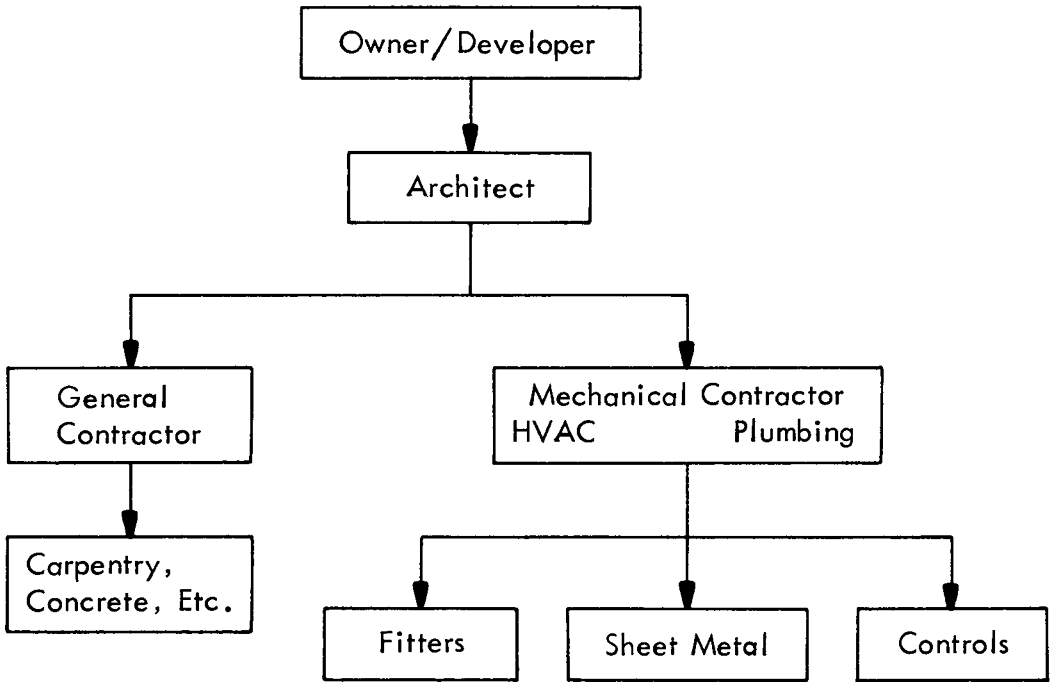
Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-3 - Functional Organization of New Commercial Market



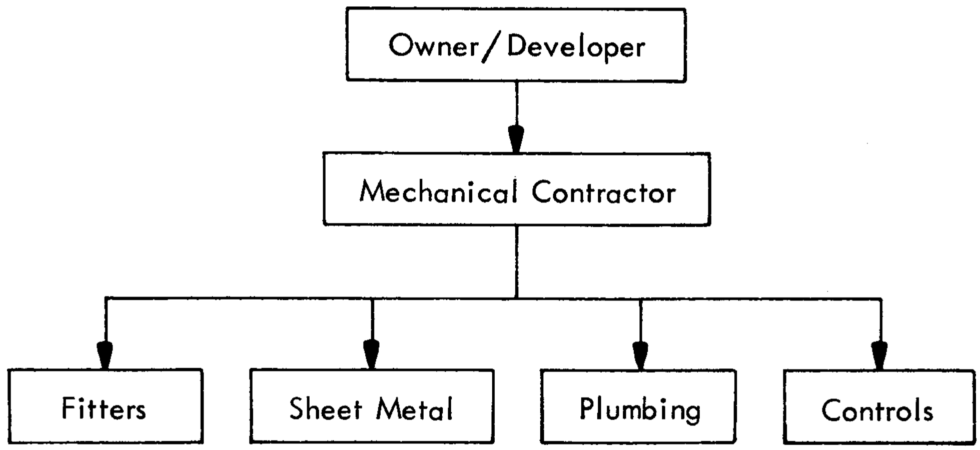
Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-4 - Functional Organization of Retrofit Commercial Market



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-5 - Functional Organization of New Residential Market



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-6 - Functional Organization of Retrofit Residential Market

TABLE A-7

FEE AND OVERHEAD SCHEDULES

Participant	%	Basis
Architect	4.5 - 8.0	Total job
Mechanical Consultant	4.1 - 10	Mechanical segment (Design)
Structural Engineer	0.5 - 2.5	Total job
General Contractor	20 - 30	Total job
Mechanical Contractor	5 - 15	Mechanical segment (Installation)
Other Subcontractor	10 - 15	Labor cost

Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Determination of the functional responsibility for purchase and installation of the solar collector system can provide wide swings in the added cost of a solar system. For example, if a system is purchased and installed by the plumber, fitter, or sheet metal contractor, the additional surcharge costs added to the installed costs can be an increase of 34 to 68%.

It is significant to note the changes between the four selected contracting routes. This is shown in Table A-8 and Figures A-3 through A-6.

TABLE A-8

COMPARATIVE FEE AND OVERHEAD SCHEDULES FOR DIFFERENT CONSTRUCTION CONTRACTORS (%)

	Commercial		Residential	
	New	Retrofit	New	Retrofit
Architect	6	10	0	0
Mechanical Consultant	2	5	0	0
Structural Engineer	1	1	0	0
General Contractor	25	0	25	0
Mechanical Contractor	10	25	10	20
Other Subcontractors	12	15	12	12
Total (not additive)	68	63	54	34

Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

It may well be that the decrease in the surcharges applicable to residential retrofits may offset the higher retrofit installation costs and make retrofits more attractive than heretofore expected.

A discussion of the roles played by the participants is as follows:

a. Architect: The architect's charges vary from 4.5 to 8.0% of the total cost of new construction. For retrofit or remodeling the charge increased to approximately 10% of the total job. The architect is responsible for the design of the structure, interfacing with the owner or developer, the general contractor, and the structural engineer. He normally obtains assistance in the development of the design package by hiring a mechanical consultant. This consultant provides the drawings necessary to define the mechanical system of the building.

b. Mechanical consultant: The mechanical consultant charges vary from 4.0 to 10.0% of the mechanical system cost. Mechanical, electrical and plumbing systems will typically be about one-quarter the total building cost. Note that the mechanical consultant is only used for commercial jobs and not for the typical residential job. The mechanical consultant is responsible for the design of the mechanical system; heating, cooling, ventilation, plumbing and anything else not directly associated with the actual construction. For retrofit applications, the mechanical consultant may be substituted for the architect.

c. General contractor: The general contractor adds 25% to the cost of the various subcontractors. He is responsible for the general supervision of the entire job and interfaces directly with the owner or developer, architect and mechanical consultant. The general contractor is involved in all new construction both commercial and residential, but may not be involved in retrofit or remodeling.

d. Mechanical contractor: The mechanical contractor charges, in addition to his own costs and overhead, an amount of about 10% of his subcontractor costs. The mechanical contractor is responsible for the procurement and installation of the equipment specified by the mechanical consultant. In residential jobs, the mechanical contractor may be substituted for the mechanical consultant; his design work is subject to the approval of the architect. For retrofit jobs the mechanical contractor may perform all the work, acting as a general contractor. In this case, he will add the 25% charge usually added by the general contractor instead of his normal 10%.

e. Other subcontractors: The other subcontractors operate with overhead rates of 30 to 50%. This overhead is normally included in the bid cost for the labor and material required.

3. Market/industry infrastructure interrelationships: The decision maker in the selection of a solar system is the mechanical engineer-designer, often with the concurrence of the architect. The mechanical-engineer-designer specifies the solar system as to function, performance and size and the architect must integrate these specifications into the overall building design. This implies that sales efforts for the collector manufacturer should be directed toward the mechanical engineer-designer and the architect. Several of the firms are presently aiming their sales effort to this market, e.g., PPG, Raypak, Chamberlain, Revere and Garden Way Laboratories. Other manufacturers are aiming their sales pitch to the ultimate consumer which in most cases is the homeowner.

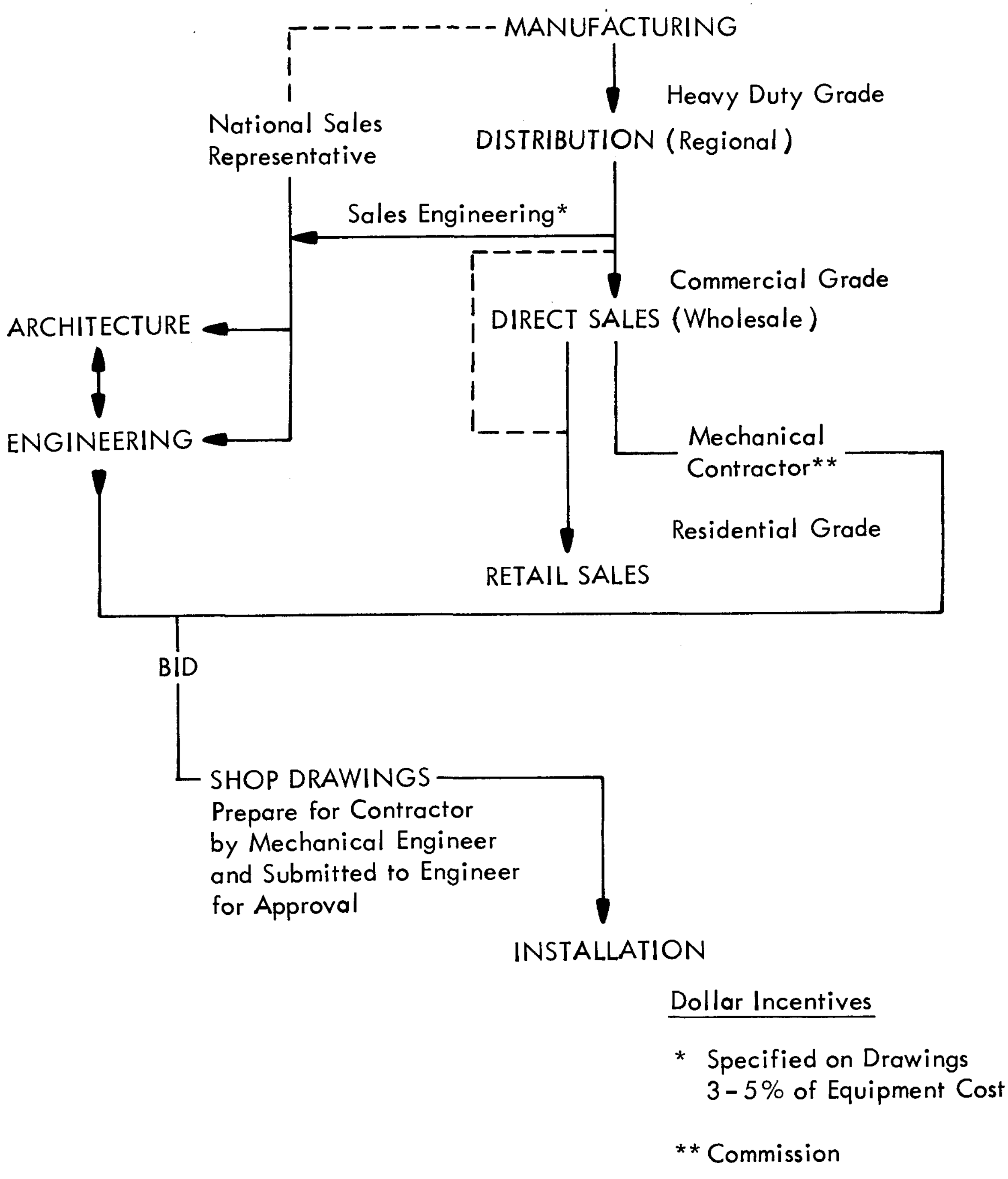
The HVAC marketing and distribution network is shown in Figures A-7 and A-8. The marketing and distribution network for the SHACOB industry is not as well established, with distribution being handled by the factory and sales handled by the home office. Growth into the normal distribution type network can be expected when the production levels reach expected goals. The segment of the SHACOB industry aiming at direct sales to owners will continue this sales technique as long as the policy is successful. This will tend to create markets near the manufacturing facilities which can compete favorably with the normal distribution network.

Certain micro markets have appeared which may not expand into larger markets, namely, swimming pool heaters in Florida and California. At present, hot water heating in Florida tends to be a micro market; however, water heating should expand into a significant nationwide market.

B. SHACOB Financial Requirements

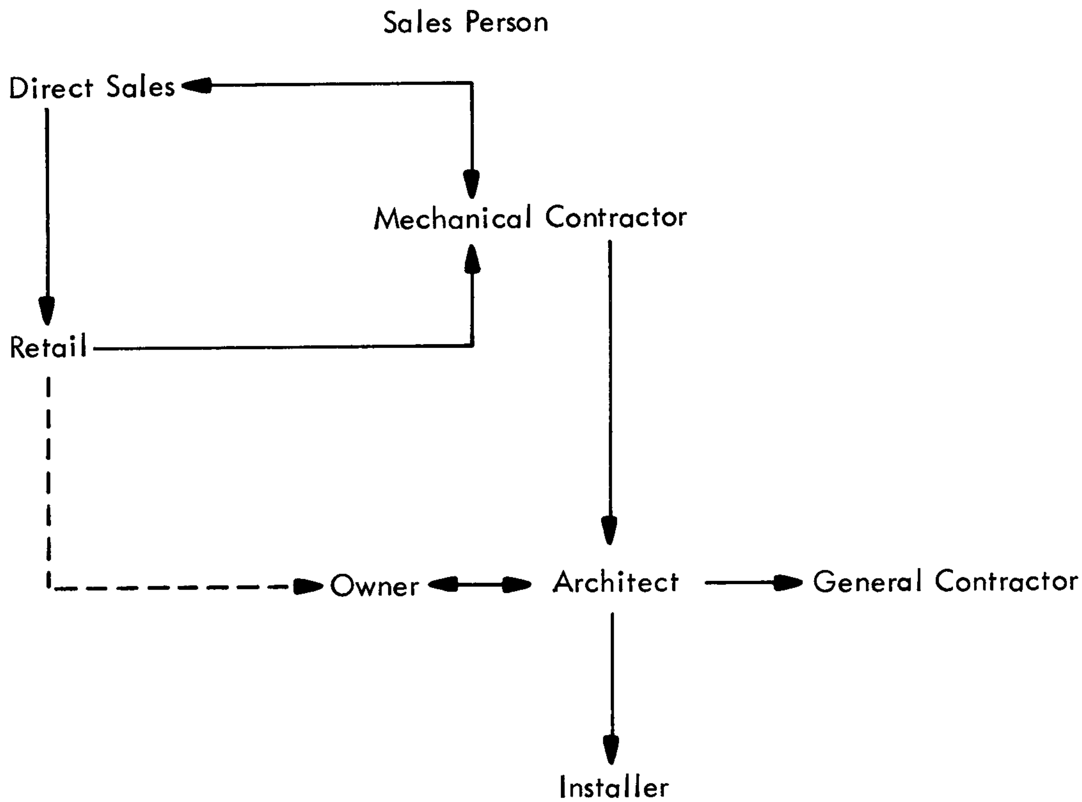
To determine the financial requirements to support a collector manufacturing operation with an output of 1 million sq ft/year, we have developed conceptual production plants which are completely automated and have minimized purchased metal forming. The financial requirements presented here are for a flat plate collector of conventional design. For this collector, we have determined the equipment necessary for the operation, estimated material cost, and labor cost, and determined the manufactured cost.

Table A-9 displays capital and operating costs for the first year of volume production of collectors. A profit center is assumed and capital outlay is limited to equipment costs, it being assumed that the building is rented. Building rental then becomes part of the overhead and thus operating costs. Operating costs also include direct wages and general and administrative costs.



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-7 - Sales and Distribution Network for New Commercial HVAC Systems



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-8 - Sales and Distribution Network for New Residential HVAC Systems

TABLE A-9

TOTAL FIRST YEAR OUTLAY FOR VOLUME COLLECTOR PRODUCTION

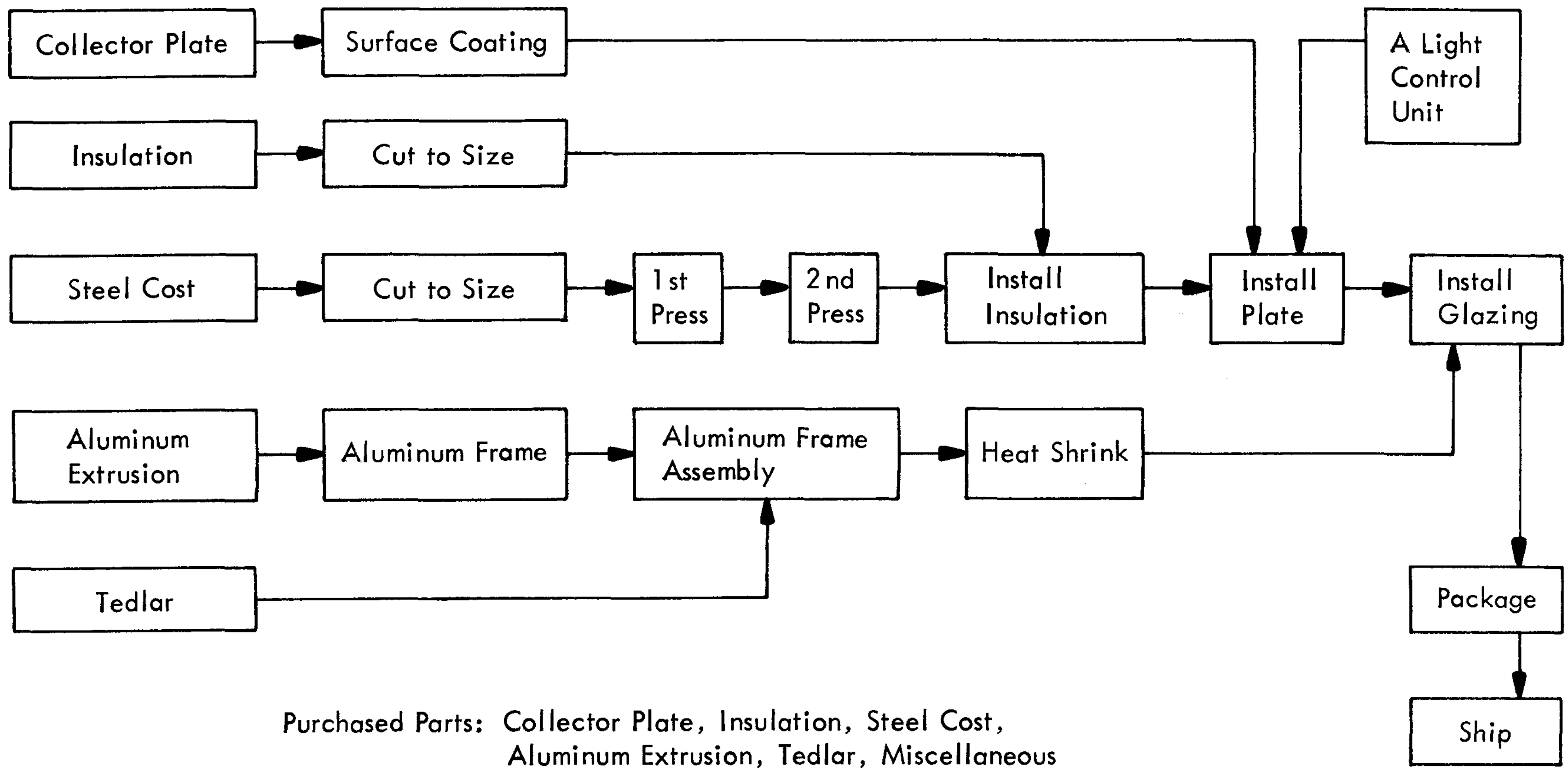
Cost Item	Conventional Design Glazing Glass	Conventional Design Glazing Plastic
Capital Costs		
Building (100,000 ft^2)	--*	--*
Equipment	$ 257,000	$ 257,000
Operating Costs		
Raw Materials	2,130,000	1,720,000
Direct Labor and Overhead	93,750	93,750
G & A	326,563	265,000
Profit	217,813	176,563
Total	$3,025,126	$2,512,313

* Building assumed to be rented.
Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

If the Owens-Illinois design is considered, the capital requirements are larger. Due to the nature of the glass business, the current pilot line can produce a million square feet of collectors at $25/sq ft. The optimal plant size for this type operation is approximately 20 to 30 million sq ft/year. Thus, the market must be perceived as larger, i.e., greater than 100 million sq ft/year for this collector system to enter the market. Cost per unit at this rate can be competitive, approximately $10/ sq ft of installed cost, with other conventional systems.

It can be seen from Table A-9 that the capital costs are in the range of $200 to $300 per thousand sq ft if the building is assumed to be rented. To cover the factory installation cost and cash flow problems, the enterprise should be capitalized at $3 to $4 million. This cost analysis was provided by Solar Corporation of America and concurred by the Food Machinery Corporation.

The process flow diagram which describes the typical conventional module is shown in Figure A-9. A list of the equipment needed to manufacture 1 million sq ft/year of collector is shown in Table A-10.



Purchased Parts: Collector Plate, Insulation, Steel Cost, Aluminum Extrusion, Tedlar, Miscellaneous

Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-9 - Manufacturing Operation for Conventional Flat Plate Collector

TABLE A-10

EQUIPMENT COST

Equipment	Conventional Design Glazing: Glass	Conventional Design Glazing: Plastic
Press Stamping	$ 50,000	$ 50,000
Press Blanking		
Trim Press	20,000	20,000
Box Dies	50,000	50,000
Roll Former	10,000	10,000
Welder Automatic	20,000	20,000
Extender	25,000	25,000
Spary Booth	2,000	2,000
Heat Oven (Paint)		20,000
Glass Handling Equipment	20,000	
Brazing Furnace	25,000	25,000
Fixtures	5,000	5,000
Conveyers	10,000	10,000
Crane	20,000	20,000
Degreaser		
Power Rolls, Tedlar		
Cutters		
Heat Seal		
Total Equipment Cost	$257,000	$257,000

Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

The SHACOB area that holds the most promise of cost reduction is the installation of solar systems. Capital requirements are small, relative to the manufacturing end. The primary equipment requirements are handling equipment to handle the collector units and the storage tank. Minimal equipment is required for the average residential sized unit. But, large arrays as found on commercial buildings will require more substantial handling equipment.

Installation work for residences will normally fall under the local HVAC contractor or solar system installer. Commercial work will fall under the mechanical engineer. Small business opportunities may occur in both the residential and commercial installations.

C. Cost Breaks

1. Cost vs. volume: Total system cost as a function of production level is shown in Figure A-10. Figure A-10 shows that the eventual total system cost is not materially effected by production rates in excess of 1×10^6 sq ft/year. The main effect of the increased production rate is the acceleration of the time required to reach the asymptope.

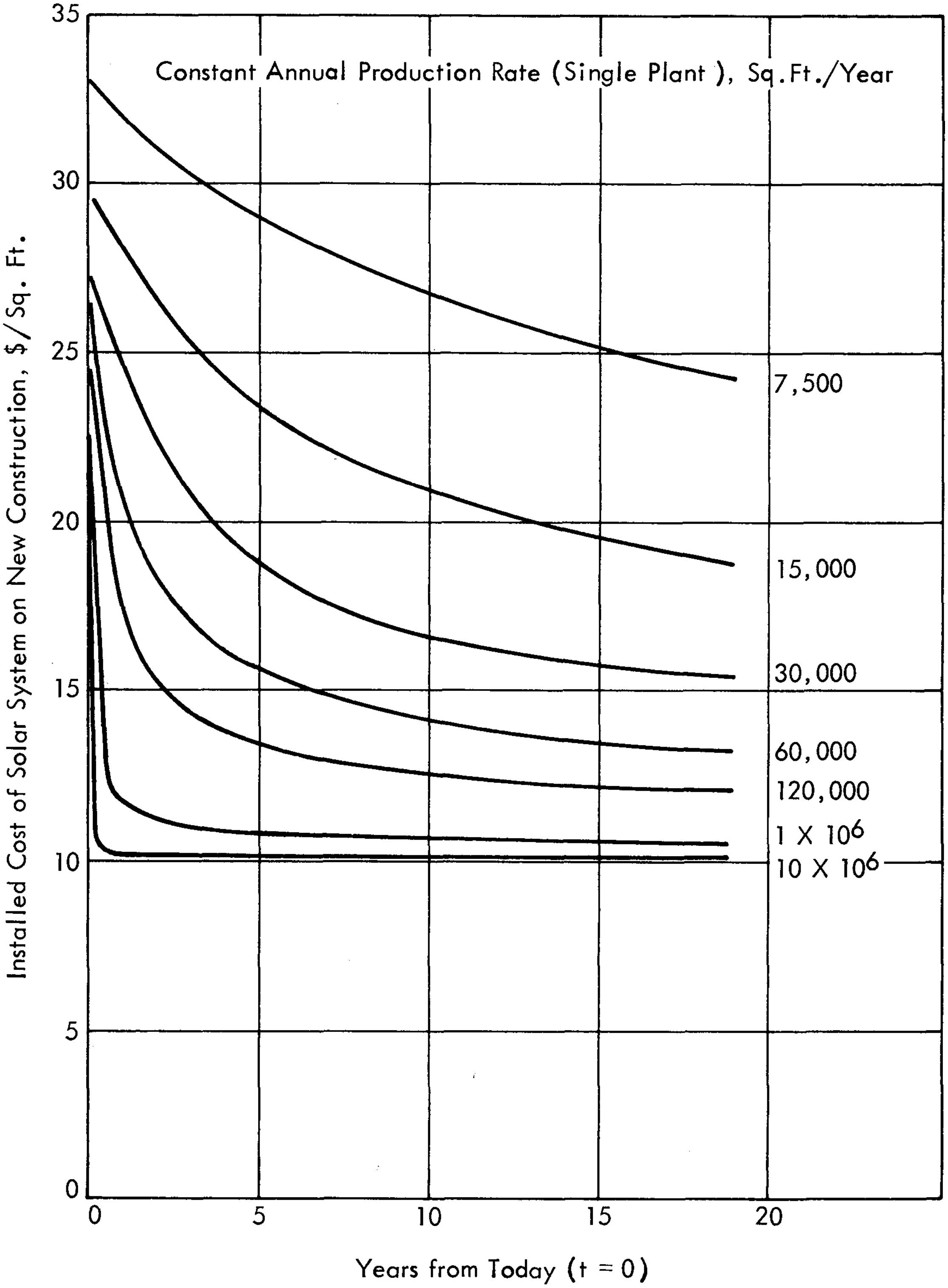
System costs were developed for one plant with sales made within a 500-mile radius of the plant.

The development of figures shown are a part of ITC Report No. 011976 submitted to the Energy Research and Development Administration, titled "Task 0, Special Report Cost/Benefit Analysis and Supporting Opinion Survey," ERDA Report No. COO-2688-1, dated January 19, 1976.

Manufacturing costs as a function of volume are shown in Figure A-11. The cost figures follow the same shape curves as found for the total system cost.

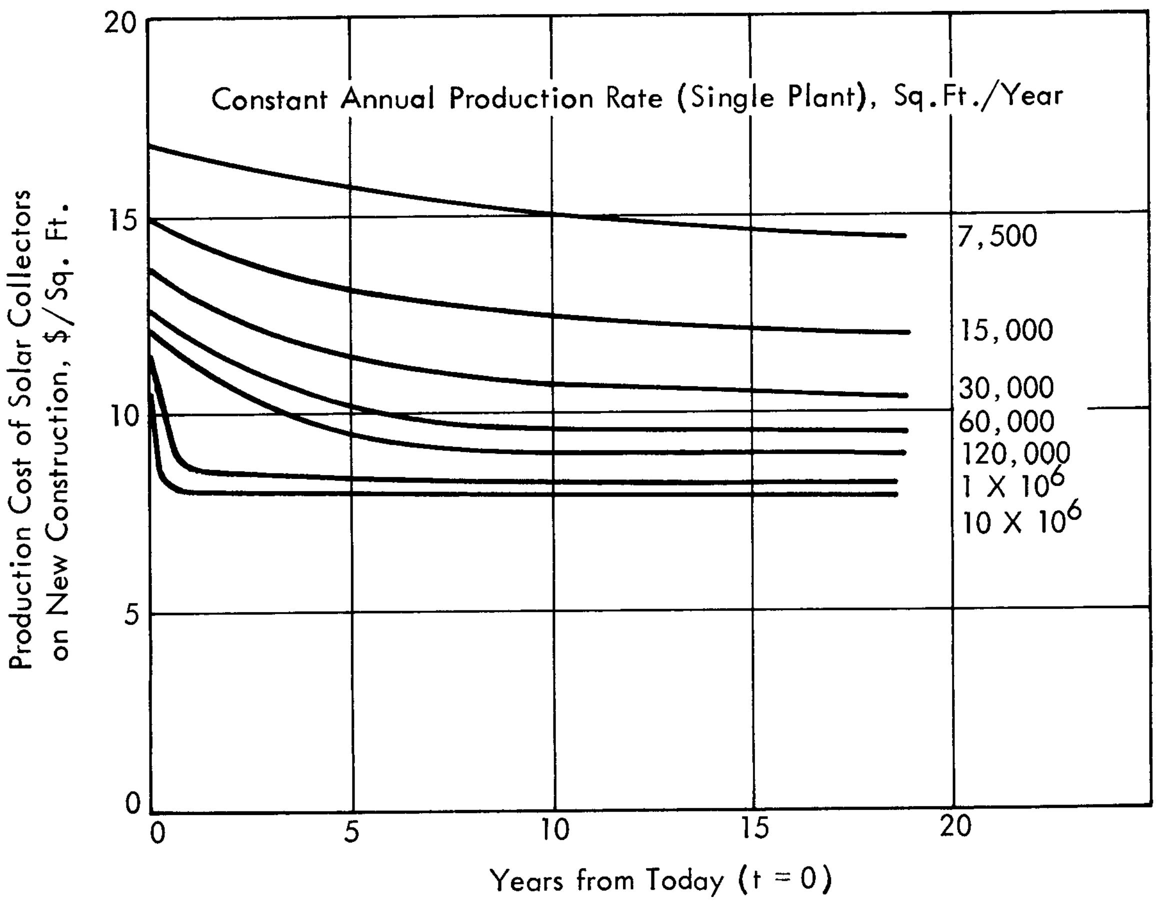
2. Cost vs. installations: Installation costs are shown for various installation rates in Figure A-12. The collector size was assumed to be approximately 3,000 sq ft.

Design costs are also a function of the number of installations and are shown in Figure A-13.



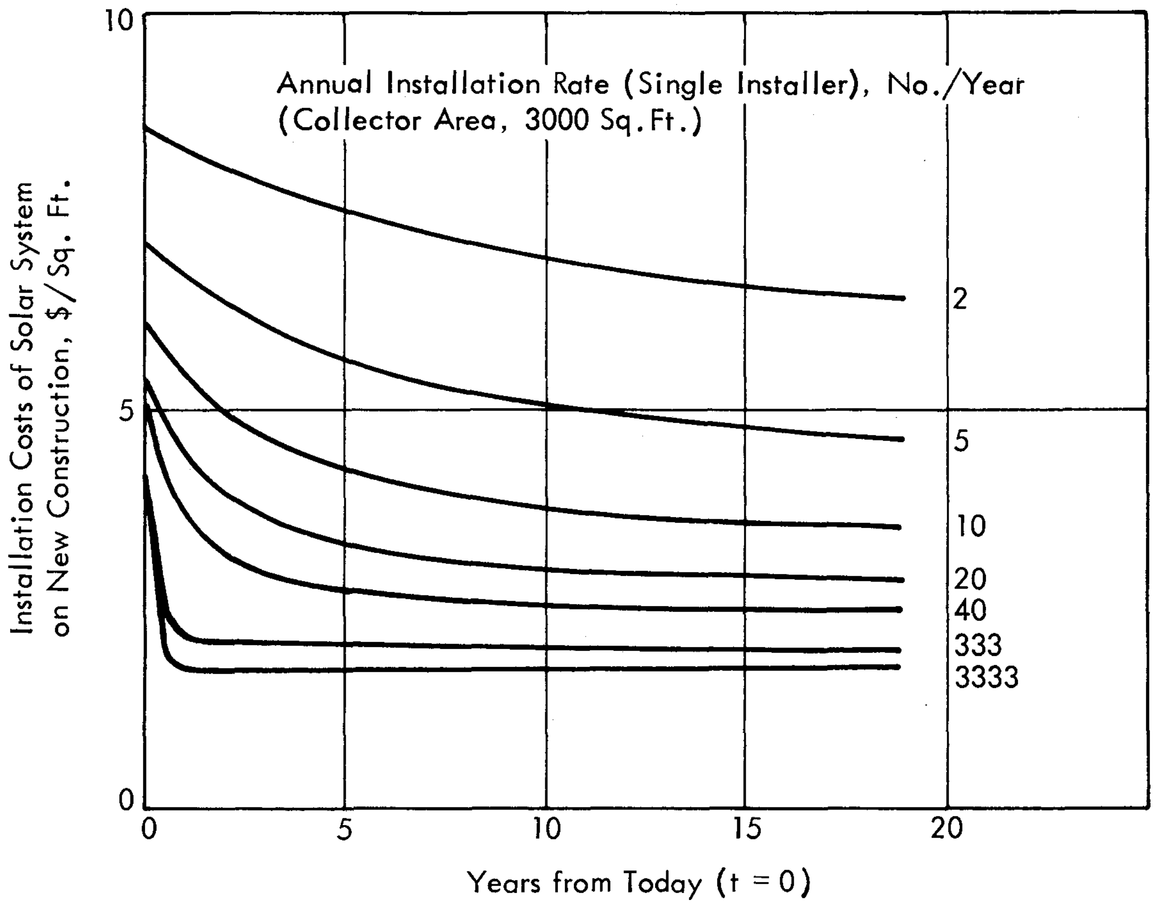
Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-10 - Unit Cost for Solar Energy System at Various Constant Rates of Production (without material substitution)



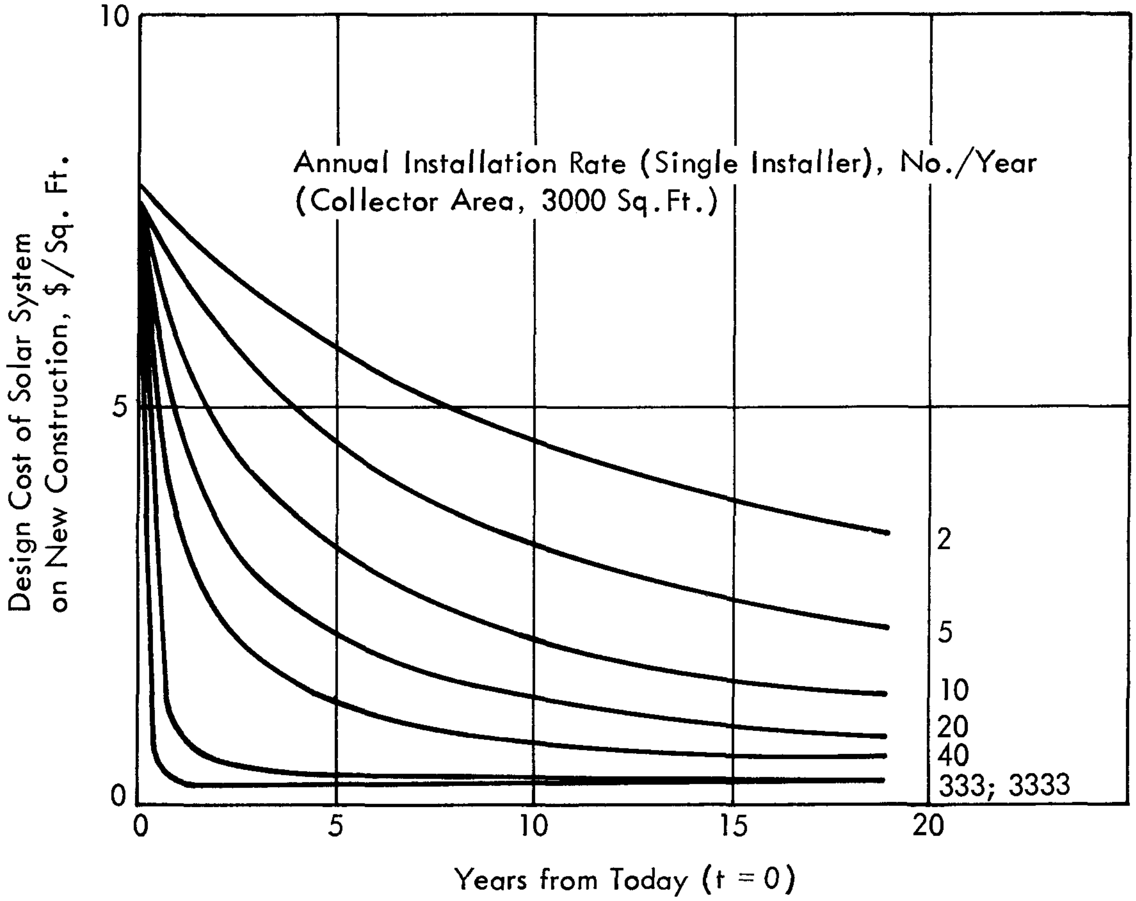
Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-11 - Unit Cost for Solar Energy Collectors at Various Constant Rates of Production (without material substitution)



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-12 - Unit Cost of Solar Energy System Installation at Various Constant Rates of Installation



Source: InterTechnology Corporation, Industry-Market Infrastructure Analysis, Report to FEA, June 1976.

Figure A-13 - Unit Cost for Solar Energy System Design at Various Constant Rates of Installation

APPENDIX B

SOLAR COMMERCIALIZATION ACTIVITIES AT THE STATE AND LOCAL LEVEL

APPENDIX B

SOLAR COMMERCIALIZATION ACTIVITIES AT THE STATE AND LOCAL LEVEL

TABLE OF CONTENTS

I. INTRODUCTION

The states will have a key role to play in the commercialization of solar energy in the United States through their ability to encourage research and development, their power to regulate production and distribution of energy, their regulatory roles in formulating and enforcing building codes, land use controls and zoning ordinances, their educational responsibilities, and their policies as consumers of energy themselves. Several states have been in the forefront in implementing policies affecting solar energy use through legislation and state programs.

This appendix* identifies state solar activities. These activities include proposed and enacted state legislation (Section II), administrative actions (Section III), cooperative programs with the federal government (Section IV) and private sector involvement (Section V). The information contained in this appendix was obtained from telephone interviews with state energy offices, from written reports, and from government agencies. This appendix is designed to give an overview of the current, significant state and local activities pertinent to the commercialization of solar heating and cooling of buildings (SHACOB). Conclusions are made in Section VI.

II. STATE LEGISLATION

A. Legislative Overview

In the past 3 years, many states have introduced legislation dealing with various phases of solar energy activities. These bills include solar tax incentives, building code revisions, easements and zoning ordinances intended to protect solar access, and state funding for research, development and promotional activities.

Of the legislation that has been enacted or proposed, tax incentives have received the greatest attention. Seventeen states now have property tax exemption statutes and at least nine other states are considering similar proposals in 1977.** Many states are reviewing more than one bill with property tax clauses.

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* A more detailed review of state solar activities is contained in Analysis of State Solar Energy Policy Options, National Conference of State Legislatures Energy Policy Project, prepared under FEA Contract No. CO-12-60496-00, and Turning Toward The Sun, National Conference of State Legislatures Energy Task Force, prepared under National Science Foundation grant (ISR-74-1552).

** Due to the timing of this report, the final disposition of these proposals is not known.

Some of these property tax statutes have an upper limit to the exemption, typically $2,000. Others limit the exemption to a specified period of years, such as 5 or 10 years. Some permit only the excess cost of the solar system as compared to a conventional system to be exempt. Colorado's law specifies that valuation for property tax purposes shall be 5% of the actual value of the system.

Another frequently considered tax action, enacted by six states, involves state income tax credits or deductions to reduce initial solar capital costs. Five additional states are proposing such an incentive in 1977. Arizona permits the acquisition and installation costs of a solar system to be amortized over 60 months, and claimed as a deduction in the state income tax return. New Mexico provides the purchaser of an approved solar energy system (meeting National Bureau of Standards' criteria) a 25% income tax credit of the cost of the system, not to exceed $1,000. If the income tax liability of the purchaser is less than $1,000, the state will make a refund.

The exemption of solar equipment from sales taxes has passed in three states and is being considered in three more states. Texas exempts the sale, lease or rental of solar energy devices from the state sales tax.

Increased public interest in solar energy has also encouraged legislative support for promotional activities and R&D programs. Nineteen states have authorized such actions and several other states are considering them. Some states have proposed the establishment of special solar energy centers. Florida is perhaps the most advanced state in establishing a solar energy center. The Florida example is discussed in some detail in Section III of this appendix. A Montana law allocates 2-1/2% (to become 4% in 1980) of the revenue from the states' coal severence tax for research and development into renewable energy resources. (Approximately $560,000 in 1976). Other states, such as Iowa, have used energy research and development funds for solar activities.

Two states have passed easement or zoning laws which safeguard sun rights. At least six other states are considering sun rights in proposed legislation. Colorado's law permits property owners to negotiate solar easements. Oregon's law permits local governments to enact zoning ordinances to ensure solar access.

Three states have implemented standards or certification statutes specifically for solar systems and five additional states are considering similar provisions. Only one state, Florida, has adopted a provision for solar systems in the state building codes. The Florida law requires all new single-family residential construction to have plumbing adaptable for future addition of a solar hot water system.

Many other types of state legislation for solar energy are still in the proposal stages. These proposals include provisions for requiring life-cycle costing, revision of utility rate structures, special solar loan programs, and public information programs.

State legislative support for solar energy is important for encouraging the choice of solar systems. Clearly, many states have begun to recognize the need for active support of SHACOB commercialization at the state level.

B. Types of Potential, Proposed and Enacted Legislation

The successful introduction of solar energy technologies will require the resolution of a number of institutional barriers. Already, many state governments have addressed barriers inhibiting the adoption of solar energy systems. Early legislative efforts have focused on addressing those ambiguities or disincentives which are parts of existing laws, regulations or tax levies. Table B-1 summarizes the types of state legislative actions relating to solar energy development. Each action is briefly described below.

1. Property tax exemptions partially or totally reduce any additional incremental assessments of the valuation of property equipment with solar heating and cooling devices by the cost of the device. Such state sponsored tax exemptions provide relatively small reductions in the incremental costs of SHACOB systems. Property tax exemptions demonstrate a state's support of SHACOB. These exemptions are characterized by low administrative costs.

2. Sales tax exemptions provide either refund or exemption from state sales tax for purchasing solar equipment. These state taxes are generally under 5% of the initial capital costs and provide a modest reduction in the first costs of a solar system.

3. State income tax deductions allow the deduction of a portion of solar system costs from taxable income up to a specified amount. Each state has different restrictions in the way the deductions are handled. Overall, state income tax deductions do not result in a major reduction in the cost of a solar system, even if the full value of the system can be deducted.

4. State income tax credits reduce the initial cost of a solar system. The impact of a state income tax credit on solar system cost depends on the limit of the credit, and whether a purchaser may take a credit in excess of his state tax liability for the year of purchase.

TABLE B-1

STATE ACTS RELATING TO SOLAR ENERGY

State Acts Relating to Solar Energy (1974-1976)	Tax Incentives			Easements and Zoning	Standards and/or Certification	Code Provisions	Provide State Promotion, Investigation or R&D	State Buildings to Use Solar
	Real Property	Income	Sales					
Alabama								
Alaska								
Arizona	●	●					●	
Arkansas							●	
California		●					●	
Colorado	●			●			●	●
Connecticut	●				●			
Delaware								
Florida					●	●	●	
Georgia	●		●					
Hawaii	●	●					●	
Idaho		●						
Illinois	●							
Indiana	●							
Iowa							●	●
Kansas	●	●						
Kentucky								
Louisiana								
Maine							●	
Maryland	●						●	
Massachusetts	●							
Michigan	●		●				●	
Minnesota					●		●	
Mississippi								
Missouri								
Montana	●						●	
Nebraska							●	
Nevada								●
New Hampshire	●							
New Jersey								
New Mexico		●					●	●
New York							●	
North Carolina							●	
North Dakota	●							
Ohio							●	
Oklahoma								
Oregon	●			●				
Pennsylvania								
Rhode Island								
South Carolina								
South Dakota	●							
Tennessee								
Texas			●					
Utah								
Vermont	●						●	
Virginia							●	
Washington								
West Virginia								
Wisconsin								
Wyoming								

Source: National Bureau of Standards, Interim Report 76-1082, "A Survey of State Legislation Relating to Solar Energy."

5. Solar easements and zoning ordinances adopted in land use plans guarantee solar access be contained in the plan.

6. Solar equipment standards establish state criteria for the rating approval of solar equipment. Such standards increase the ability of financial institutions to assess the quality of a solar system, and aid building contractors and designers in specifying equipment. Another benefit of this type of legislation is to generate consumer confidence in the performance of solar systems. Rigid standards, however, have the potential of hindering innovation and increasing the solar equipment manufacturer's administrative costs.

7. Solar codes establish a set of regulations controlling the incorporation of solar systems into buildings. As was mentioned previously, in Florida, for example, residential structures must be designed to facilitate the future installation of solar energy equipment. Generally, building codes are enacted into law by local governments. However, 21 states have recently set statewide codes for either mandatory or voluntary application.

8. Low interest loans for SHACOB act to reduce the monthly financing costs of the system. Interest rate subisdies can have a significant impact on SHACOB costs. No state government has yet to propose state financial interest subsidies for solar systems. This is probably due to the considerable direct and administrative costs of such a state program.

9. Loan guarantee programs reduce the burden of risk to financial institutions of default on solar home mortgages. No state initiated loan guarantee programs for SHACOB have been enacted.

10. Grant programs are designed to defray the costs of purchasing and installing solar systems. A state sponsored grant program would require a large administrative structure for review and action on grant applications. State activity to date has been primarily restricted to participation in federal solar grant programs.

11. Solar installations on state buildings have been planned and appropriated by five states as demonstrations of solar heating and cooling systems. Benefits include state promotion of solar energy use, provision of data on solar system operating and maintenance costs, and local experience in installing solar systems.

12. State participation in federal demonstration programs requires state and federal cooperation and serves to help extend the coverage and impact of the federal demonstration programs. States play an important role in developing the building code exemptions necessary to implement the program.

13. Research and development (R&D) programs have attracted the attention and appropriations of several state governments. State funds are often used to attract federal support. Funds have been made available to universities, research institutes and for the establishment of solar energy research centers. Benefits include potential revenue for the solar industry, employment opportunities in-state, and stimulation of the construction and building industries.

14. Information programs are designed to overcome the lack of public awareness of the costs and benefits of solar energy systems. Information programs have been targeted at consumer groups, architects, financial institutions, solar manufacturers and local government officials. At present, the lack of adequate public information is probably one of the most critical barriers to SHACOB commercialization.

15. Utility rate restructuring concepts are being investigated to assess interface between solar systems and the utility. The primary objective of these efforts is to establish fair and equitable rates for solar users and conventionally equipped buildings, which also cover the utility cost of service. Four types of utility rate structures are mainly being considered: (1) inverted rate structures, (2) off-peak pricing or peak surcharges, (3) time of day pricing, and (4) demand charges for solar energy users.

III. ADMINISTRATIVE ACTIONS

A. State Agencies

As seen in Table B-2, many states are actively involved in sponsoring some form of solar energy research, promotion or demonstration. While state energy offices range in size from 3 to 30 people, solar energy is often handled by only one individual who also handles alternative fuels or consumer information. Some states such as Florida, New Mexico, Arizona and California, however, have made a substantial commitment to solar energy and have established solar energy centers, offices, or commissions, employing as many as 40 full-time people.

An excellent example of state activities in solar commercialization is the Florida Solar Energy Center (FSEC) in Cape Canaveral. The FSEC was created as a result of state legislation passed in 1974. The FSEC director reports to the vice chancellor for academic programs at the State University System of Florida. The FSEC conducts a wide range of activities facilitating the use of solar energy in Florida.

TABLE B-2

STATE ADMINISTRATIVE ACTIONS RELATING TO SOLAR ENERGY

State Administrative Actions Relating to Solar Energy	Solar Energy Center, Office or Commission	Solar Information Program	Solar Publications	State Participation or Sponsored Workshops and Seminars and/or Training Programs on Solar	Solar Energy in State Buildings
Alabama					
Alaska					
Arizona	●	●	●	●	
Arkansas					
California	●	●	●	●	●
Colorado		●	●	●	●
Connecticut			●	●	
Delaware					
Florida	●	●	●	●	
Georgia					
Hawaii					
Idaho					
Illinois			●	●	
Indiana					
Iowa			●	●	●
Kansas					
Kentucky					
Louisiana					
Maine					
Maryland					
Massachusetts			●		
Michigan			●		
Minnesota			●		
Mississippi					
Missouri					
Montana					
Nebraska					
Nevada					●
New Hampshire					
New Jersey					
New Mexico		●	●	●	●
New York					
North Carolina					
North Dakota					
Ohio					
Oklahoma					
Oregon					
Pennsylvania					
Rhode Island				●	
South Carolina					
South Dakota					
Tennessee				●	
Texas					
Utah					
Vermont					
Virginia	●			●	
Washington				●	
West Virginia				●	
Wisconsin					
Wyoming					

Source: Telephone conversations with State Energy offices.

Equipment for testing solar collectors has been purchased and installed by FSEC to provide testing capabilities required for research efforts. Approximately 40 collectors have been submitted by manufacturers for testing and certification by FSEC. Figure B-1 shows a certification label which is attached to collectors meeting established minimum standards.

CERTIFICATION

This certifies that solar collector

Model No. x-xx-0000

Manufacturer

Solar Energy Sales
100 Solar Road
Solar City, Florida xxxxx

has been tested for thermal performance and meets the Minimum Standards established by the Florida Solar Energy Center as directed by Section 377.705, Florida Statutes. This certification does not represent an endorsement of the product by the Florida Solar Energy Center or the State of Florida.

THERMAL PERFORMANCE RATING*

Low Temperature (35 C; 95 F)	**xxxxxkJ/day**	**xxxxx Btu/day**
Intermediate Temperature (50 C; 122 F)	**xxxxxkJ/day**	**xxxxx Btu/day**
High Temperature (100 C; 212 F)	**xxxxxkJ/day**	**xxxxx Btu/day**
Collector Area	**xxm^2**	**xx $ft.^2$**

* Rating based on an assumed standard day for Florida

A Florida Solar Energy Center Consumer Data Sheet which summarizes test results for this collector is available from the seller

A test report may be obtained from the

Florida Solar Energy Center
300 State Road 401
Cape Canaveral, Florida 32920

Figure B-1 - The FSEC Collector Certification Label

One of the most important services offered by the FSEC is the publication and dissemination of information pertaining to all aspects of solar energy. Three publications are of special interest. These are:

1. "Florida Solar Energy Equipment and Service" - a 100-page directory of solar equipment and services available in Florida from 77 companies. This directory provides essential information to designers on the availability of solar components.

2. "A Guide to System Sizing and Economics of Solar Water Heating in Florida Residences" - a 63-page document explaining the operation, sizing, economics, installation and maintenance of solar hot water heaters. This guide provides regionally specific design information for solar system designers.

3. "The Solar Collector" - a quarterly newsletter describing activities at FSEC and items of general interest concerning solar energy in Florida. This publication provides a wide group of people general information on solar developments in Florida.

Intrastate activities by the FSEC include assistance in the formation of the Florida Solar Industry Association, which is currently working with the center in developing standards for solar equipment. The center also evaluates the many solar bills (17 in 1977) which are presented to the state legislature. Sixteen grants from FSEC to public and private universities within the state (totaling $260,000) have provided "seed money" to researchers enabling them to more easily seek additional research funding from the federal government and other sources. The FSEC is working with the State Energy Advisory Council, the State Energy Office and the Florida Department of Commerce on such topics and demonstrations as solar energy applications to public schools, a program for manufacturing solar collectors within the state's correctional institutions, and encouragement of solar industry development within the state.

Florida has been a leader in the coordination of solar energy activities within the state. The FSEC is an excellent example of state involvement in solar energy, providing a model to be closely studied by other states.

B. State Information Programs

Most states, no matter how small, have a public information dissemination program where solar facts sheets, booklets and pamphlets from the federal government are distributed to interested parties. Arizona, Iowa, Illinois, Massachusetts, and Florida published their own material on solar energy such as guides to buying solar hot water heaters, a directory of solar manufacturers, basic consumer information on solar applications, or how to apply for federal grants for solar energy.

Many states have participated or sponsored workshops or seminars on various aspects of solar energy. Workshops for engineers, contractors, home builders, solar manufacturers, and interested consumers have been sponsored by some states, for example, Connecticut, Virginia, Florida, California, and Colorado. Funds for seminars and workshops generally come from the state education offices or through the universities. California has established a "Solar Technician Training Program" to teach marketable skills to technicians in preparation for the future solar market.

Some grants and education funds are directed towards R&D in the state universities and other state schools. Usually, the funds are a supplement to federal funds to broaden the approach or impact. Most universities identified in the states are working on some aspect of solar energy ranging from testing solar collectors to evaluating solar hot water systems, to demonstration projects for heating and cooling buildings.

C. Solar Energy in State Buildings

Five states have appropriated funds for the demonstration of solar heating and cooling on state owned or financed buildings. Colorado allotted funds for the north campus of the Community College of Denver. Iowa is completing the installation of solar heating systems in the state capitol complex in Des Moines. A solar heating system has been installed in a research facility operated by the University of Nevada. New Mexico has constructed a laboratory and office building with solar heating and cooling. New Mexico is also constructing a demonstration project on the campus of the state university with state research and development funds.

California has supplemented funds from various sources (ERDA, HUD and private organizations) for installation of solar hot water and space heating in buildings in community colleges and state universities.

Other states are considering putting solar applications on state office buildings in order to show state support for solar energy. Iowa is proposing a feasibility study on the life-cycle costing of solar versus conventional systems for state buildings. The main barrier to implementing such a program is the availability of state funds for long-range projects.

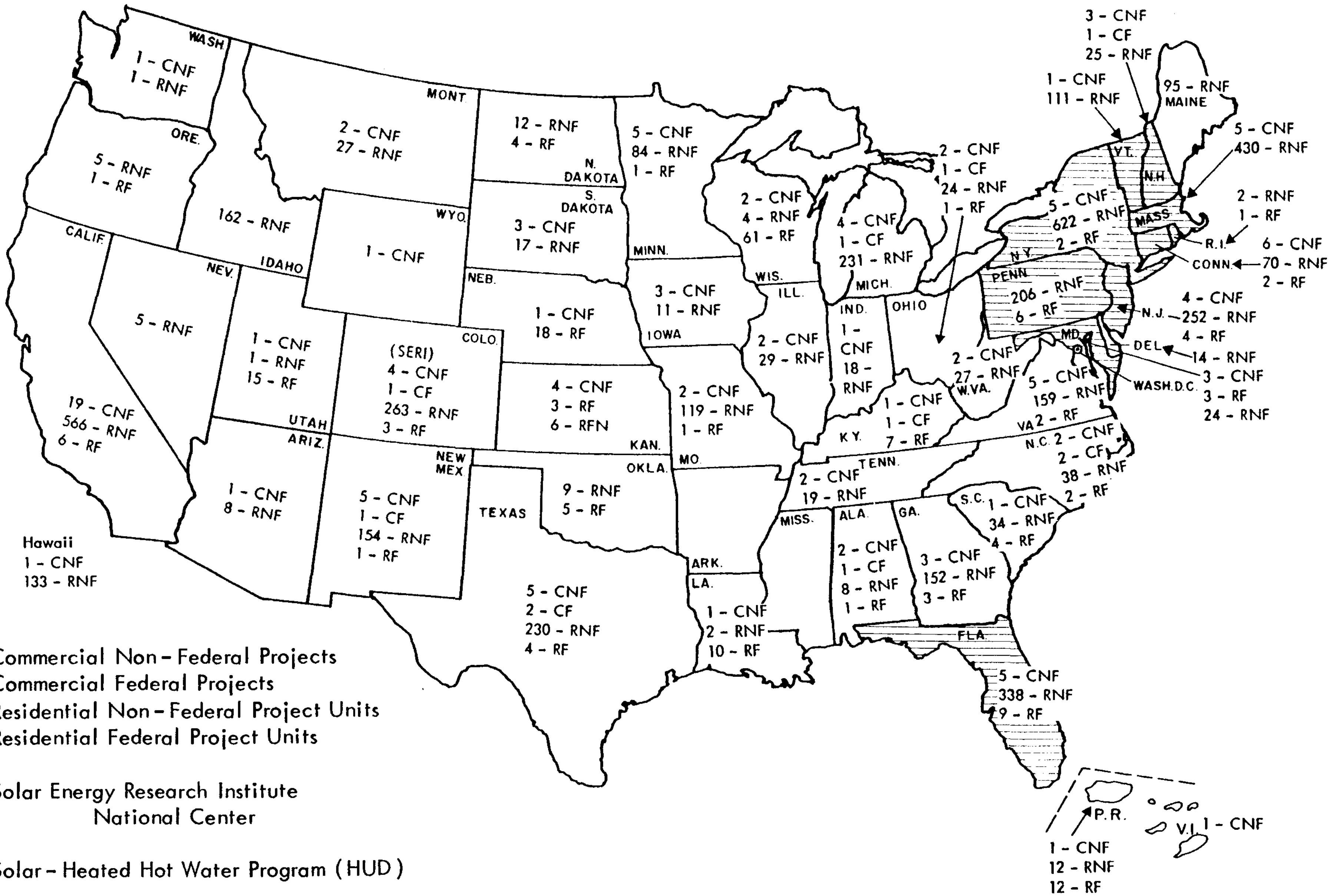
D. State/Utility Interface

Public utilities will play an important role in solar commercialization. Each state has a different set of rules and guidelines that regulate the utilities. The SHACOB utility interface is discussed in detail in Appendices C and D. As the states play a major role in utility regulation, any programs directed at modifying utility practices to encourage SHACOB will require state support.

IV. FEDERAL/STATE

A. National Solar Energy Research Development and Demonstration Plan (RD&D) (ERDA)

The primary goal of the National Solar Energy RD&D Plan is to work with the private sector to develop, demonstrate and introduce economically competitive and environmentally acceptable solar energy systems. The plan is largely responsible for procurement programs attuned to the various states and local municipalities as well as those having nationwide impact. Figure B-2 summarizes many joint federal and state program activities.



CNF - Commercial Non-Federal Projects
CF - Commercial Federal Projects
RNF - Residential Non-Federal Project Units
RF - Residential Federal Project Units

(SERI) - Solar Energy Research Institute National Center

Solar-Heated Hot Water Program (HUD)

Source: National Program for Solar Heating and Cooling of Buildings - Project Data Summaries, ERDA 76-127, Vol. 1, August 1976 (updated to include HUD Cycles 2 and 3 RNF Grants and ERDA Cycle 2 CNF Grants).

Figure B-2 - State Activities in Federal Funded Programs

One program is the Commercial Demonstration Program in non-federal buildings. In 1976, the projects selected for this program were drawn primarily from the ERDA Program Opportunity Notice (PON). There were 32 state applications accepted for this program selected from the PON. The most active participants were California with eight projects, and Maryland and Florida with five and three, respectively. Eighty non-federal commercial projects were funded in the second cycle of the ERDA commercial demonstration program.

Another federal procurement program deals with research in solar energy. In 1976, the ERDA unsolicited proposal program attracted 200 unsolicited proposals from various colleges and universities from a wide cross-section of states for research related grants. Out of those 200 proposals, 25 were awarded grants.

The Solar Energy Research Institute (SERI) proposal arrangement is perhaps the most pertinent to state solar advancement and is the most recent procurement program offered by ERDA. Proposals for this program were accepted from commercial or state and local governmental entities. The initial role of SERI will be the performance of analysis, assessment, information dissemination, research activities, and provision of technical consultation to other elements of the ERDA solar energy program. There were 19 proposals submitted. Midwest Research Institute, in cooperation with the State of Colorado, was awarded the SERI contract. The establishment of four regional centers managed by SERI will increase regional participation in the SERI effort.

B. Residential Demonstration Program (HUD)

The Department of Housing and Urban Development (HUD) manages the Residential Demonstration Program in non-federal buildings. Projects are selected from the Request for Grant Applications (RFGA) issued by HUD. The overall administration of energy research programs undertaken by the federal government rests with ERDA, but HUD has with ERDA joint responsibility for this residential demonstration program to investigate practical application of solar energy in heating and cooling. The majority of states are presently involved in this program (see Figure B-2).

Major elements specified in the program include:

- Demonstrations to give visibility, experience to builders and developers, and data on market acceptance.

- Standards development for FHA and the industry.

- Market development activities including studies of barriers and constraints, and development of tools to overcome them.

- Information dissemination to the building industry, including contract management of the National Solar Heating and Cooling Information Center.

The Solar Heating and Cooling Demonstration program has been expanded to put solar-heated hot water systems in 10,867 residential units to induce manufacturers to step up sales of equipment. The funds will be allocated to 11 states where homeowners paid high electric heating bills in 1976. The states will then distribute the funds to homeowners and builders-developers who want to install the solar-heated hot water system.

Under the HUD program, the states are authorized to pay $400 per unit, about half the solar hot water system cost, to homeowners and builder-developers for the solar-heated hot water hardware, usually consisting of one or two collector panels, tank for pre-heating water, and pumps and controls. Installation cost is not included in the payment.

A similar program for commercial users aimed particularly at hotels and motels is being developed by ERDA.

C. Energy Extension Service

The primary objective of the Energy Extension Service (EES) is to encourage energy consumers such as homeowners, small businesses, schools, and state and local governments, to adopt measures which save energy or utilize non-depletable energy sources, such as solar energy. These groups now have difficulty in obtaining reliable information pertaining to these energy measures from convenient, objective sources in which they have confidence. The EES would assist these energy users by providing, on a personalized basis, information and assistance regarding the availability, technical details, and energy and cost savings potential of energy efficient techniques. Solar systems would be included in the domain of the EES.

In partnership with ERDA, state governments would have a leading role in the development and implementation of the service, to assure that the information and assistance provided meets state and local needs, and is effectively coordinated with other energy programs operating in the states.

Services offered would vary by state and locality to fit the specific interests of the consumer. Examples are energy audits for commercial establishments, mini-audits for homes, and energy information "hot lines". The states would be required to use, to the extent possible, existing organizations for delivering services to energy consumers, in order to keep overhead costs low and avoid the creations of large or new bureaucracies. These organizations would include relevant state and local agencies, university engineering extension services, the Cooperative Extension Service, and other groups that have suitable information or assistance capabilities.

In line with the FY 77 authorization bill signed by the President on May 27, 1977, ERDA has initiated a pilot program involving 10 states to be selected competitively. A key ERDA management function will be evaluation of the pilot program to assess:

- program costs versus actual or estimated energy savings attributable to the service;

- the most effective ways of designing and operating a service; and,

- the utility of the service in providing information on institutional barriers preventing adoption of energy measures and feedback on local needs to be factored into the nation's energy research plans.

After approximately 2 years of state pilot service operations, ERDA will initiate a nationwide EES program.

D. State Solar Energy Commercialization Program

The Federal Energy Administration (FEA), pending approval, has developed plans to initiate a "State Solar Energy Commercialization Program" to assist the states in planning and implementing programs designed to accelerate solar commercialization. The recent FY 77-78 budget for solar commercialization would allot $225,000 for a state and local sector analysis which would address existing laws, ordinances, and zoning requirements, plus a comprehensive update of recent legislation and initiatives affecting solar energy implementation under state and local jurisdiction.

Developing model state commercialization plans would be provided through state cooperative agreements. A report has been prepared by the Florida Solar Energy Center under a cooperative agreement between FEA and the State of Florida entitled "Solar Energy Commercialization at the State Level: The Florida Solar Water Heater Program." This report is an excellent example of the efforts achievable through state and federal cooperation.

The program includes:

- joint state/utility planning projects designed to achieve maximum utilization of solar systems and consistency with electric utility operations;

- programs to utilize solar energy in state/local public buildings;

- state solar energy quality assurance programs to assure that solar equipment sold or manufactured in a state meets appropriate criteria;

- educational/training programs for builders and homeowners;

- state/local regulations where necessary, e.g., building codes, land-use planning, sun rights, etc.

- economic incentives;

- state participation in federal/state/utility comprehensive regional commercialization strategies for large scale solar electric power generation, such as the Southwest Project.*

V. PRIVATE/LOCAL CONSUMER ACTIVITIES

Interest in solar energy in the private sector has been substantial in the past 3 years. One state, Colorado, claims to have acquired "practically overnight" at least 30 private groups working on solar energy. Many of these groups are environmental, consumer or citizen organizations which have been concerned with the future supplies of energy. Most of these organizations have their own public information programs which work either in conjunction with federal or state programs or develop their own communications depending on available funds. Several state energy offices with small staffs refer most of their inquiries to these private organizations which are better equipped to handle questions. Other groups involved in solar energy are volunteer groups which usually run on small budgets but have expertise in various aspects of solar energy. The full impact these groups will have on bringing solar energy to the marketplace has not been assessed. However, several states have indicated the value of these organizations to their operations in providing consumer and technical information and in lobbying for solar legislation.

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* The Southwest Project, currently in the early planning stages, is a federal project coordinated by FEA to identify and develop special institutional arrangements for assuring substantial levels of utilization of solar electric power generation via wind, photovoltaics, and solar thermal technologies in the greater Southwestern U.S. regions.

VI. RECOMMENDATIONS AND CONCLUSIONS

Proposed legislation strongly implies more solar legislation will be passed this year in many states. A close watch on upcoming proposals, enacted legislation, and an analysis of these measures should be undertaken to assess the potential impact legislation will have on solar commercialization.

Many states have administrative powers not requiring legislation which could be used to promote solar energy such as funds available from the education system for R&D and demonstration projects, public information programs, or restructuring utility rates for solar energy backup systems. A detailed study on the potential each state has administratively for solar energy development is needed.

Private organizations have made significant contributions to solar energy development in some states. The impact of these private groups on solar commercialization should be addressed in more detail.

One observation from speaking to all the states is that there is very little, if any, communication among the states. Most states could benefit from other states' experiences or expertise in solar. The federal government should be considering ways in which the states could better coordinate their solar activities.

APPENDIX C

ELECTRIC UTILITY INTERFACE

APPENDIX C

ELECTRIC UTILITY INTERFACE

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This appendix* is divided into two sections. Section I identifies seven key issues related to the impact of utility made structures on solar heating and cooling systems (and to some extent wind energy systems) and examines each one in detail. Section II describes seven possible government actions that could address these issues. References are provided at the end of the appendix.

I. KEY ISSUES INVOLVED IN ASSESSING THE IMPACT OF UTILITY RATE STRUCTURES ON SOLAR HEATING AND COOLING SYSTEMS

Seven key issues emerge in an examination from an FEA viewpoint of the interaction between utility rate structures and solar heating and cooling systems. These issues involve:

- Adequacy of the present approach to ratemaking,
- The influence of load factor and demand on rate design,
- The actual nature of solar heating and cooling system backup energy requirements,
- The problems imposed on the utility by distributed solar-electric generating devices that operate intermittently,
- Whether the choice and design of backup energy source should be administratively controlled, and, if so, how control can best be effected,
- Whether public utilities should participate in the manufacture and ownership of solar heating or wind energy systems,
- How the value of savings of non-renewable energy resources resulting from solar energy collection can be included in evaluating possible actions with regard to rates.

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* This appendix is reprinted, with only minor modifications, from a previous study for FEA, Energy Rate Initiatives: Study of the Interface Between Solar and Wind Energy Systems and Electric Utilities, FEA Contract No. P05-77-4242-0, Office of Synfuels, Solar, and Geothermal Energy, Federal Energy Administration, pp. 23-97, March 31, 1977.

This section takes up each issue in turn, presenting the important factors in each and discussing their implications to possible government actions.

A. Suitability of Present Approaches to Ratemaking

Issue 1: Is the present, cost-oriented approach to utility rate structures flexible enough (from an administrative point of view) to create equitable charges to consumers using distributed solar and wind systems for heating, cooling, and generation of electricity?

Assessment: Existing approaches to rate design are intended to make rates somewhat cost-responsive, and can address the characteristics of solar and wind energy system backup loads. However, solar and wind energy system backup loads involve patterns of demand and energy use that may differ significantly from those of electric resistance heating customers, and rate designs should reflect these differences. The design of equitable rates requires some data on how the backup requirements of solar and wind energy systems compare with utility load curves. These data are not presently available on an adequate scale. Such data are not required for the design of peak-load-pricing rates, but are essential to understanding the effect of peak-load-pricing rates on the design and economics of solar and wind energy systems.

1. Criteria for a satisfactory rate structure: The primary criteria of a sound rate structure are fairness, adequacy, and efficiency. Structures are adequate when they provide sufficient revenue for a fair return; and fair when each customer is charged for what he uses and no more. The need for adequacy recognizes that all costs incurred by the utility are ultimately passed on to the consumer. Rates are efficient when they allocate scarce resources in a socially optimum manner.

The requirements for fairness and adequacy together imply that rates should be made as cost-responsive as possible. These criteria must be balanced against another not mentioned above, the need for simplicity in the rate structure. This need arises from two requirements:

- The rate structure must be simple enough in concept to be understood and accepted by the general public, and to be weighed by them in decisions involving energy use.
- The rate structure must be simple enough to be administered without undue costs in data collection on customer usage.

The history of utility rate structures has reflected the desire to strike a balance among these criteria that is appropriate to the technical and economic conditions existing at the time. It is useful to begin by reviewing the traditional approaches to ratemaking and how they attempt to be cost-responsive.

2. Traditional approaches to ratemaking: Traditional approaches to ratemaking divide costs into three classes:

- Costs incurred in serving the individual customer
- Costs associated with being able to supply his maximum power demand
- Costs arising from supplying his energy requirements

Construction of a rate structure involves the recovery of these charges in a way that matches the customer's energy use, while maintaining simplicity of structure and data collection.

COST COMPONENTS

Customer Costs	Demand Costs	Energy Costs
Meter and Service	Generating facilities	Fuel
Meter Reading	Environmental Control Facilities	Water
Billing	Transmission and Distribution	Certain Operating Expenses that vary with Energy Production
Customer Service	Maintenance of facilities	
	Taxes	
	Depreciation	
	Insurance	
	Return on Investment	
	Certain Operating Expenses that Vary with Demand	

a. Declining block rate (Typical for residential and small commercial customers)

- First Block includes customer costs, part of demand costs plus energy costs
- Next Block(s) include balance of demand costs plus energy costs
- Last Block includes only energy costs*

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* It should be noted that some existing declining block structures do not adhere strictly to this pattern, but include some demand costs through the final blocks.

The most widely used rate structure is the declining block rate. This rate gained popularity when most utility load was lighting load, which peaked sharply in the evening hours.[1] "The declining rate structure was intended to encourage short-run load-factor* improvement and long-run capacity expansion. In the past when this increased use caused system expansion, technological improvements generally meant that the utilities still lowered their unit or average costs. Now, because of substantial increases in generating and transmission costs, reduced economies of scale, and altered use patterns (i.e., air conditioning and the summer peak) which reflect a higher association between final block usage and peak responsibility, the declining block rate can no longer be justified for its promotional usefulness, according to critics."[2] The history and intent of the declining block rate structure are subjects of considerable disagreement.

b. Demand/energy rate (Typical for large commercial and industrial customers)

- First charge includes customer costs and demand costs

  Demand costs are usually based on the highest 15- or 30-minute segment of measured usage

- Balance comprised of energy costs

The demand/energy rate can be made to track the cost of power closely for customers whose peak usage occurs during the peak load period. It is commonly used for large commercial and industrial customers, where the quantity of power used justifies the additional cost of metering.

A modified form of demand/energy rate has been proposed to one public utility commission to be applied to residential customers using electric heat alone or as a solar backup. This modified form is discussed briefly under the next issue.

c. Less commonly used rate structures

(1) Time-of-use incentives: A time-of-use incentive provides separate rate schedules for daily peak and off-peak periods. As customers shift their pattern of use to take advantage of these rates, the utility's load factor tends to improve. An improved load factor allows the utility to increase its use of high-efficiency, base-loaded generating plants, realizing additional savings through lower energy costs and fossil fuel savings.

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* Load factor is the ratio of average to peak power demand, defined on a daily or annual basis.

If the rate structure defines the peak period by time of day, additional metering cost is incurred due to the need to record peak and off-peak usage separately. In an attempt to approximate such a differential at lower cost, some rate structures employ seasonal rate differences (e.g., higher summer rates for a summer-peaking utility). Such a structure is reasonable in the sense that the annual peak usually involves utilization of the most expensive facilities, but it does not address daily load peaks, which contribute significantly to the cost of energy production. Time-of-use incentives are currently being discussed in 22 states and one federal jurisdiction.[3/]

However, there are limits to the benefits that can be attained through improved load factor. One reason is that the utility may find that its capacity is now limited by its transmission and distribution facilities. Another is the fact that utilities employ off-peak periods to take generating units out of service for preventive and other maintenance. If demand is nearly constant, the utility must build additional base-load generating capacity to accommodate this need.[4/] This need for reserve generating capacity is especially critical in situations such as the severe weather of January 1977, when unusual cold weather combined with a shortage of natural gas to create a heavy electrical demand on a number of summer-peaking eastern utilities. Thus, the importance of maintaining adequate reserve capacity must always weigh heavily in plans to improve the utilization of electric generating capacity.

(2) Load management contract rates (Interruptible service)

- Customer accepts limitations on time of energy use in return for a lower rate

- Utility incurs load control costs, but may significantly improve its load factor

Such rates have had limited residential application in the U.S., typically for domestic hot water heating, but have been used more extensively in Europe in connection with thermal energy storage (TES) space-heating systems, where the system peak occurs in the winter. U.S. systems generally peak in the summer, although some evidence indicates we may be returning to winter peaks.

3. Incremental costs as a basis for utility rates: Time of use incentives, either as differential rates for off-peak periods or as contract rates for interruptible service, are based on a recognition that the costs of producing electricity vary with the load on the utility. The question of whether to base utility rates on incremental as opposed to average costs

is currently being investigated by eleven states and the District of Columbia.[3] As Uhler has pointed out,[5] this controversy actually involves two issues:

- Whether and to what extent costs that vary with the level of demand should be reflected in utility rates.

- Whether and to what extent incremental costs - as distinguished from average costs - should be used as a basis for utility rates.

A discussion of the concept of incremental costs and their justification as a basis for utility rates is beyond the scope of this paper. The subject will be discussed at length in Section IV of the forthcoming FEA Report to Congress under Title II. The problem includes issues ranging from practical details (such as whether the additional metering costs are justified) through financial questions (such as whether utility revenues will become unacceptably volatile) to broad philosophical questions (such as whether utility rates should be based on cost or value).

If, however, peak load pricing rates that adequately reflect production costs can be developed, they would act as signals to the designer of solar heating equipment. The designer of a solar system would see that his electric bill for backup energy would be lower if he could arrange to draw backup energy during off-peak hours when the price was low. If the off-peak period did not coincide with the time when his system required backup energy, he might employ the thermal storage component of his solar heating system not only to store solar energy for later use, but also to store off-peak electric energy for later use.* Off-peak energy storage might simply require a change in the control system, or it could involve additional heating elements or even alterations in the design and capacity of the thermal storage unit. Analysis of the costs of different configurations would reveal how extensive the additions could be before the savings in electric bills would no longer justify their cost. The utility would find that its economic position was improved, for those customers who chose to draw energy during the utility peak would pay the peak cost of energy, while those who exploited the off-peak rates would present backup energy loads at the time the utility could most economically serve them. Thus, the overall combined cost of backup energy to the customer and utility would be minimized.

4. <u>Impact of requirement for simplicity on the cost-tracking of rate structures</u>: As will be more thoroughly discussed in connection with the next issue, the costs of serving a utility customer are significantly

* Petersen presents a conceptual example of such a system in Reference 6.

affected both by his peak demand and how it varies with time (his individual load factor). In order to achieve simplicity in rate structures and their associated metering costs, customers are grouped into representative classes. If a customer's load factor and magnitude and time of peak demand correspond to the average values assumed for his customer class, then his electric bill will closely track his cost of service to the utility.

5. Effect of heating system energy use patterns on electric bills: In a later subsection under Issue 3, a number of different heating system configurations are considered, with some general inferences about their peak demands and total energy use. The peak demand of some of these is as low as one third of the base case of electric resistance heat, which happens to be the highest. Load factors range from less than half the base case to about 10% more. (One system employing annual storage has a similar low peak demand but a higher load factor than the base case.) Because the ratio of average demand to peak for these systems is different from the base case, conventional rates - particularly block rates - are unlikely to track costs of service, as discussed below.

a. Declining block rates: When a declining block rate is constructed, customer costs are usually covered in the first block, as discussed under Issue 1. The demand costs are distributed through the first and later blocks, guided by the total energy use and load factor of the average customer for the class of service in question - lighting, lighting plus electric heat, etc. This distribution of demand cost is arranged so that the elctric bill for the average customer will just cover his cost of service.

Consider a solar heating system configuration that imposes the same maximum demand as electric resistance heating unit, but uses less total electrical energy. The customer will pay his customer costs in the first block, but in using less energy will pay only the proportion of his demand costs that have been assigned to the early blocks. If his reduced consumption is such that he does not use energy in all blocks in which demand charges are distributed, the utility will not recover its entire cost of service.

The non-solar system with annual energy storage has a lower peak demand than either the solar or electric resistance system, and has a higher load factor as well. As is evident from Figure C-2, the costs to the utility involve a higher proportion of energy to demand because of the higher load factor. But if such a system is billed under a declining block rate addressed to electric resistance heating customers, the lower energy consumption will again base most of the bill on the lower blocks. Because of the radically different pattern of energy use, this system pays more than its share of demand charges, and the utility recovers more than its cost of service.

b. Demand/energy rate: If the demand and energy are measured separately for each customer, the bills for different heating systems can be made to agree more closely with costs. However, if demand and energy are measured without recording the time they occur, rates may still fail to track costs if the peak customer demand does not coincide with the peak utility demand. As Cicchetti shows,1/ both demand and energy costs vary during the peak and off-peak periods. If the customer's peak use occurs during the utility off-peak period, and the rate structure ignores this, he may be charged a higher rate than his cost of power. (Obviously, if the peak load occurs entirely during the off-peak period, the customer load tends to improve the system load factor, allowing greater employment of low-cost, base-load generating capacity.)*

c. Time-of-use differential rates: Customers having different patterns of power demand can in principal be equitably treated under time-of-use differential rates that accurately reflect incremental costs.

- Such billing requires more complex customer metering, adding to customer costs.

- As discussed under Issue 1, the internal computation of incremental costs is a complex, though not insurmountable problem.

- Heating system designers would see in a time-of-use structure clear signals as to how to design their equipment for minimum backup energy bills. If the structure truly reflects incremental power production costs, the designs will tend to minimize utility costs as well, and therefore, total costs to society.

B. Influence of Load Factor and Peak Demand on Rate Structures

Issue 2: What is the influence of system peak demand and load factor in the ratemaking process?

Assessment: The load factor, which reflects the daily and annual time variation of the aggregated load served by a utility, directly effects both the demand component and energy component of cost. If solar systems achieve wide acceptance, the combined effect of their individual load factors could alter the load factor of the utility as a whole.

1. Influence of demand on energy costs: The overall load of an electric utility is likely to take the general shape of Figure C-1, which has been drawn for a summer-peaking utility.

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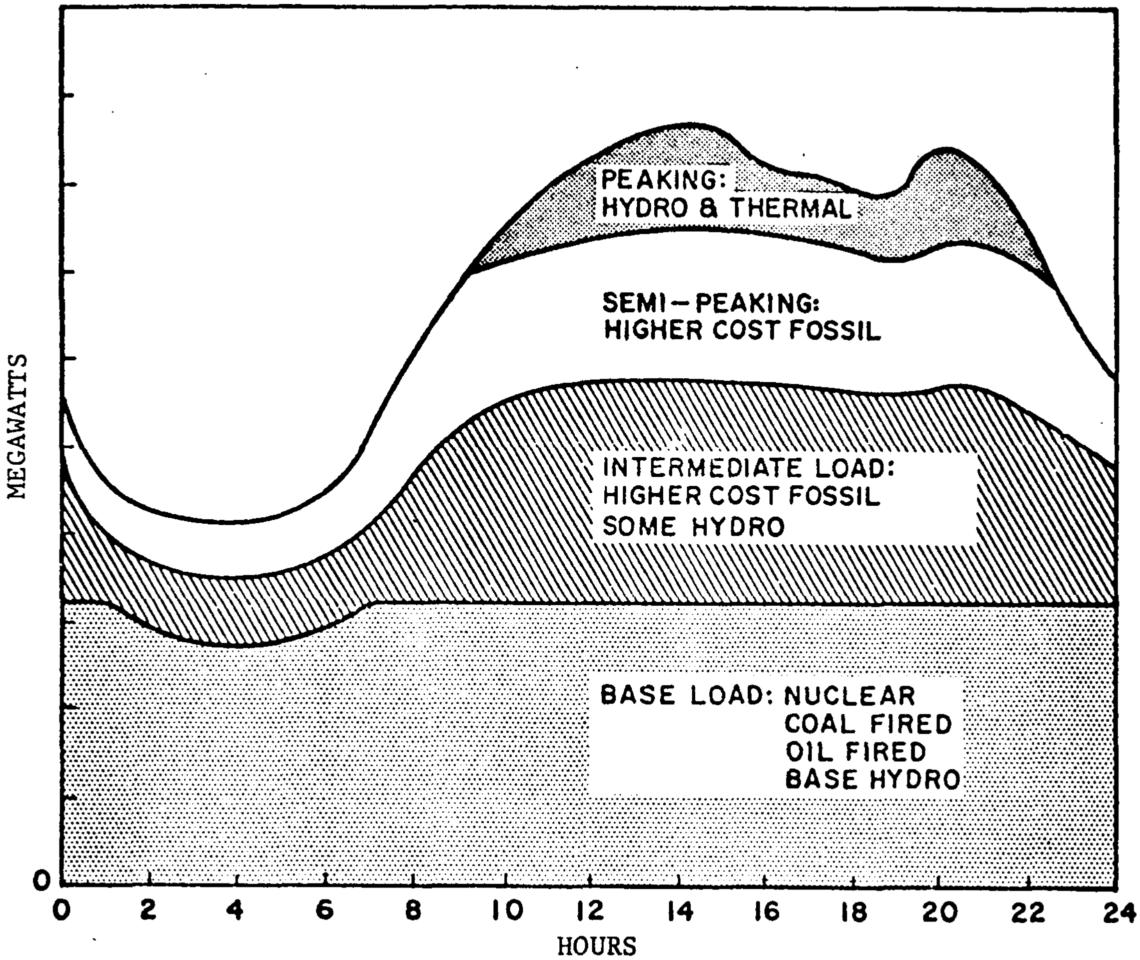
* There are some limits to the extent to which higher load factors benefit the utility, as discussed under Issue 5.



SOURCE: Load Management, Its Impact on System Planning and Operation, Phase 1, Report of the EEI System Planning Committee, Edison Electric Institute, EEI Pub. No. 76-28, New York, N.Y., April 1976.

Figure C-1 - Typical Generation Dispatch Summary Peak Day

Utilities tend to classify their generating facilities as:

Base Load - Usually nuclear, or large, new coal-fired power plants. These have low unit energy generation costs, but take a long time to start up and bring on line.

Intermediate Load - Usually older, less efficient fossil-fired plants.

Peak Load - Usually oil- or natural-gas-fired plants and gas turbines. These have high unit energy costs, but can be brought on line in much less time. Sometimes hydroelectric units are in this classification because of their speed in coming on line.

A utility will try to serve as much as possible of its load with the cheapest, base-load plants. As the load rises, based on its past experience, it brings intermediate plants on line. During the peak it depends on the quick response of its costly peak load facilities or purchases power from adjacent systems.

Thus, the cost of energy varies with the power demand on the system, and higher system load factors tend to reduce energy costs for all users.

The daily or annual load factor of the system is defined as the ratio of its average load to peak load throughout the day or year. If this ratio is high, implying a relatively steady load, the utility can depend mostly on plants with base-load characteristics and can achieve a low average unit energy cost. If the load factor is low, then the utility's generating mix must include a large proportion of quick-responding peak load plants, and the average unit energy cost will be higher.

The peak power demand affects not only the generating mix, but also the transmission and distribution networks, which must be sized to carry the peak load. If the load factor is low, most of the time the transmission and distribution networks will be carrying only a fraction of their rated capacity, and most of the invested capital will be idle.

2. <u>Effect of load factor on the proportions of a customer's cost of service</u>: Figure C-2 shows how the proportions of the electric utility's customer, demand, and energy costs vary with an individual customer's load factor. In this example, it is assumed that the customer has a fixed maximum demand that occurs during the utility's peak period, but that his load factor may vary. At very low load factors, as on the left, the utility must run a power line capable of serving a load that is turned on for only

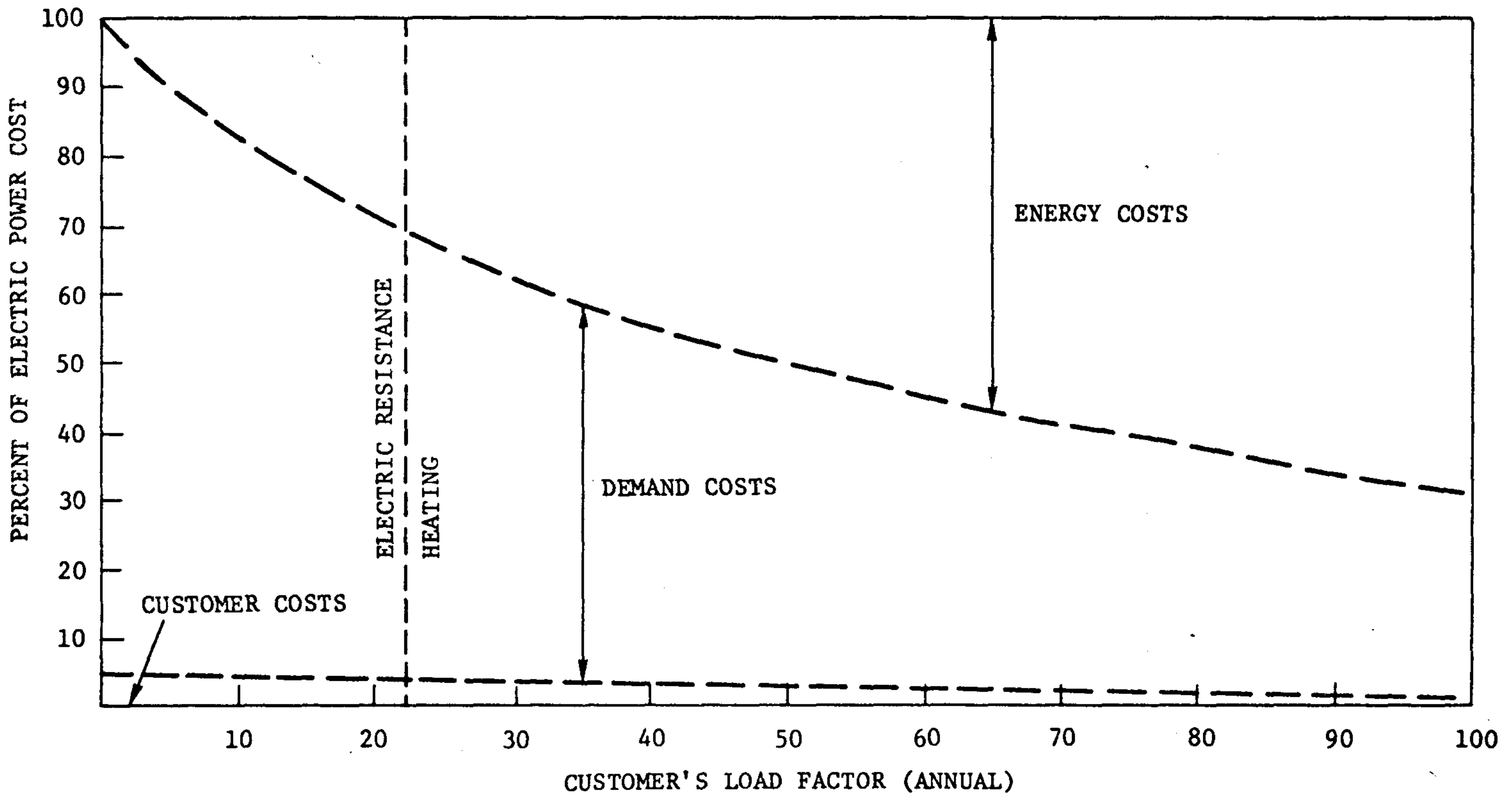


Figure C-2 - Electric Power Cost Components Relationship With Customer's Load Factor (Annual) a brief period; the customer buys very little energy and the bulk of his service cost results from the customer cost and demand costs. At high load factors, the customer employs his electric service at its rated capacity nearly all the time, so the proportion of his total costs due to demand is much less.

The vertical dotted line has been drawn for a load factor of 0.22, typical of an electric resistance heating customer. If the customer has a lower load factor, the figure implies that--as long as his rates are based on a group average of 0.22--he will pay less than his proper share of demand costs. If he presents a higher load factor, he will pay more than his proper share of demand costs.

It should be noted that load factor is not the sole determinant of demand cost. Where a customer's peak use occurs during the utility's off-peak period, the influence on demand cost may be quite small. This, of course, is where thermal energy storage is of value, as discussed under Issue 5.

A demand charge for residential solar users was recently considered by one public utility commission as a means of compensating the utility for its costs incurred in serving customers with low load factors. In this instance a "ratcheting" demand charge was proposed, one in which the maximum 15-minute demand incurred in any month would determine the demand charge for the next 12 months. If a higher demand occurred during the 12 months, the demand charge would immediately rise and remain at the higher rate for the subsequent 12-month period. The name "ratcheting" was applied because the rate acted like a mechanical ratchet rising to and holding at the highest level of the demand. Such a rate would protect the utility by recovering the customer's demand cost, no matter how low his load factor. It may be overprotective since it ignores the fact that the peak solar demand may not occur during the utility's peak load period.

3. Implications

- Because of the importance of system peak demand and load factor in determining cost-of-supply, utility rate structures should accurately reflect this impact.

- For utilities where solar systems pose utility factor problems, public utility regulatory bodies should consider adopting time-of-use and load-management contract rate structures designed to reflect total costs of power generation and distribution for that class of customers who demonstrate low daily load factors.

C. Nature of the Solar Heating Backup Demand

Issue 3: What is the customer load factor and actual backup demand imposed on a utility by the backup energy requirement of a solar heating and cooling system?

Assessment: Available data are inadequate due to the small number of solar heating installations, their limited experience, non-uniform data collection practices, and wide divergence of system designs. Published reports are in conflict over the exact impact of solar heating backup demands on public utilities. This is due to the fact that most writers have simulated system performance, and the difficulty of obtaining valid input data for the simulations adds uncertainty to the results.

Such data are only sparsely available, and cannot be directly compared among installations. Data collection should include peak demand and its time of occurrence, as well as insolation, weather and wind velocity data, and other pertinent factors.

1. Results of simulation studies: The results of published studies are in conflict over the exact impact of solar heating backup demands on public utilities. Lorsch[7/] states flatly, "A solar heating customer would appear to a winter-peak utility exactly the same (in terms of demand) as an all-electric heating customer, and . . . he contributes to the winter peak generation requirement." Lorsch developed load factor comparisons, based on an assumed maximum diversified demand of 10.2 kw for both conventional and solar heating customers.

	Load Factor (Heating Only)	
	January	Annual
Conventional	38.5	17.6
Solar	16-26	11-18.2

Note that the solar load factors are lower than for the conventional system, and therefore, less desirable to the utility. This is evident both on an annual basis and for January, the month of peak heating demand.

Petersen conducted a baseline study similar to that of Lorsch, but using data for Boulder, Colorado. He concluded: "During (several periods of time when the solar system cannot supply energy) the amount of auxiliary energy is essentially equal to that which would be required by a conventional heating system."[6] Petersen says "essentially equal" because he found that even for the 36-hour period when the solar system placed its greatest demand on utility backup energy, the solar collectors managed to contribute 17% of the total heat load of the house.

Petersen went on to investigate the opportunity for load factor improvement that arises from the inclusion of storage in the solar system. He found that by taking advantage of the ability to store backup energy, the solar energy system user can shift his peak electricity requirements to periods when the aggregate energy demand on the utility is low. An example is demonstrated where, through predictive storage* of energy, the solar system's peak-period demand is limited to no more than two-thirds of the peak-period demand of an all-electric heating system.

Feldman's results are more optimistic.[8] He concludes that energy storage plus the solar input are such that the solar energy system is capable of providing some or even all of the thermal requirement of the building at the time of utility peak. In two of the 7 years analyzed, the solar building required no auxiliary energy during the peak period of the peak load day. Feldman also found that a higher percentage of the solar building's consumption is off-peak:

	Ratio of Peak to Off-Peak Use
Conventional Building	0.100
Solar Building	0.066

Taken together, these studies present a conflicting picture of the solar backup demand and its effect on the utility. It must be borne in mind that all three studies are simulations, based on different assumptions and system designs, as shown in Table C-1. The Lorsch and Feldman reports only considered storage for the solar system. The backup system came on-line upon demand. Thus once the solar storage was exhausted, due to several cloudy days, the system became pure resistive and contributed to peak period demand. The Petersen report used storage serving both the solar system and the utility backup system. Thus much of the backup demand could be shifted off-peak. One problem with this system is that charging up the storage off-peak at night reduces the solar efficiency during the next day since the solar has to pump against a higher storage temperature.**

* Predictive storage uses weather forecasts to optimize energy storage in advance of backup needs.

** An extensive discussion of the role of thermal energy storage as an interface between solar systems and the electric utility is contained in Reference 16.

TABLE C-1

CRITICAL ASSUMPTIONS IN SOLAR SIMULATIONS

Problem Area	Method of Treatment		
	Lorsch[7]	Petersen[6]	Feldman[8]
	(Building sites: Philadelphia and Allentown, Pennsylvania)	(Building site: Boulder, Colorado)	(Building sites: Colorado Springs, CO and Madison, WI)
Solar Input			
Hourly data is collected at few sites in the U.S. At other sites simulations must rely on approximate data.	Data not available for either site; Becker-Boyd approximation based on ASHRAE insolation data	Not stated	Data not available for either site; simulated with weather data
Weather Data			
Data collection site may not match house site	Philadelphia and Allentown data were available	Boulder, Colorado data were available	Colorado Springs used Boulder data Madison data were available
Year selected for analysis	1964--closest to 1963--70 average	1956	Boulder--1956 Madison--composite data of 1948-56
Configuration	Storage for solar energy only	Storage for solar plus predictive storage	Storage of solar energy only

2. Does the solar backup energy demand coincide with the utility's peak load period?: One unresolved parameter of the backup demand of solar heating systems may be essential to evaluating their impact on the utilities that serve them: Are the peak backup load days for solar systems the same as the peak load days for electric resistance or heat-pump systems?

Again, the published reports that are based on simulations are in conflict. Lorsch concludes that the solar customer imposes a capacity requirement identical to that of a conventional electric heating customer.[7] Feldman, on the other hand, believes that solar buildings seem to mitigate peak demands when compared to conventional buildings.[8] His report and that of Jardine[9] express the belief that the solar and conventional peaks may not coincide, reasoning that the peak load day for a conventionally heated house is likely to occur when a cold, high-pressure system causes temperatures to plummet. But such weather typically brings clear, sunny days that allow the solar system to collect energy. In contrast, the solar system requires backup principally on dark cloudy days, and cloud layers tend to reduce nighttime radiation from the earth and to keep minimum temperatures up. Furthermore, Jardine points out that the peak backup demand of the Project Phoenix house when operating in the solar mode was only 42% of the peak demand when operating in the conventional mode.[9]

If a utility is to depend on diversity between the peak demands of solar and conventional heating customers, it must have firm evidence that such diversity exists, and the evidence is not conclusive on the existence of such diversity, let alone its magnitude. Furthermore, the answer may depend on the details of weather and climate in different regions.

3. Heating system design affects both the total need and use pattern of backup energy demand: The introduction of solar energy collectors, thermal storage units, and heat pumps has created a wide range of options in selecting the configuration of a home heating system. Where oil and gas are available as backup fuels, they may be compared with electricity in making the choice. Figure C-3 illustrates just a few of these, chosen to illustrate the variations in requirement for electrical energy that they imply.

System 1 is the conventional electric resistance system for space and water heating and electric air-conditioning. (Air-conditioning was included in the examples because reversible heat pumps offer this feature, and it was desired to compare all systems on an equal performance basis.) This system imposes a high peak demand, on the order of 25 kw, but since electricity supplies all of the heating load and is used for air-conditioning in the summer, the load factor is about 0.22.

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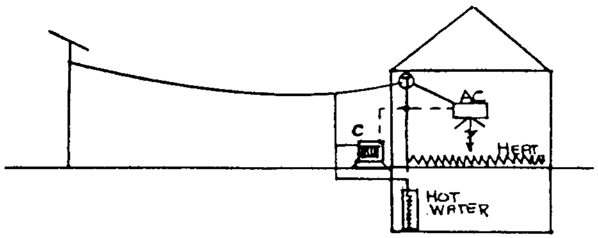
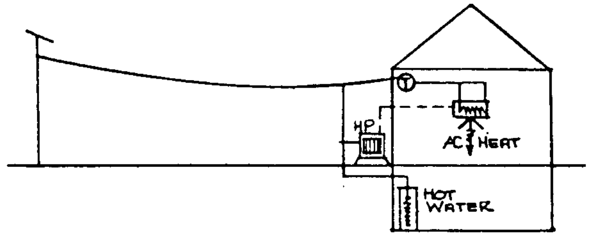
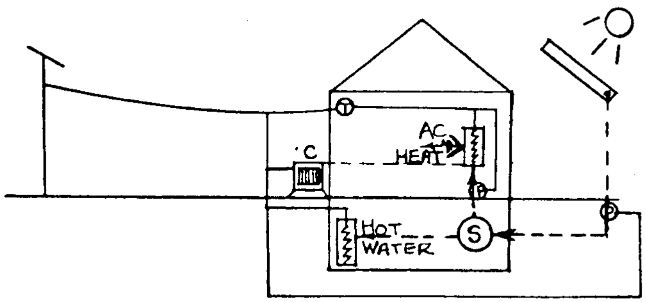
* Data typical of the Public Service Company of Colorado.[10]



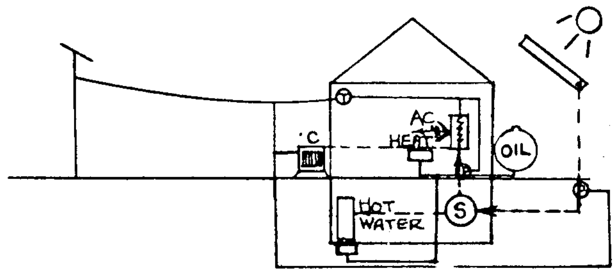
1. ELECTRIC RESISTANCE SPACE AND WATER HEATING WITH AIR CONDITIONING



2. AIR TO AIR HEAT PUMP FOR HEATING AND COOLING, ELECTRIC RESISTANCE BACKUP AND WATER HEATING

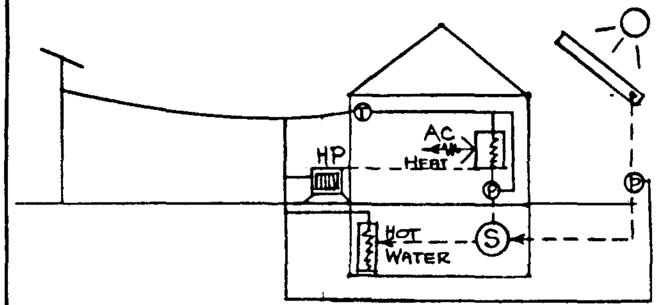


3. SOLAR SPACE AND WATER HEATING, 1 DAY STORAGE, 60% SOLAR UTILIZATION, ELECTRIC RESISTANCE BACKUP, ELECTRIC AIR CONDITIONING

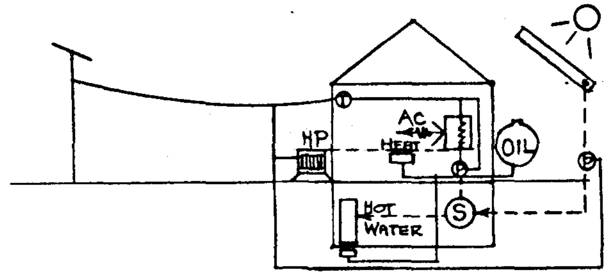


4. SOLAR SPACE AND WATER HEATING (FLUID OR AIR COLLECTORS), 1 DAY STORAGE, 60% SOLAR UTILIZATION, OIL HEAT BACKUP, ELECTRIC AIR-CONDITIONING

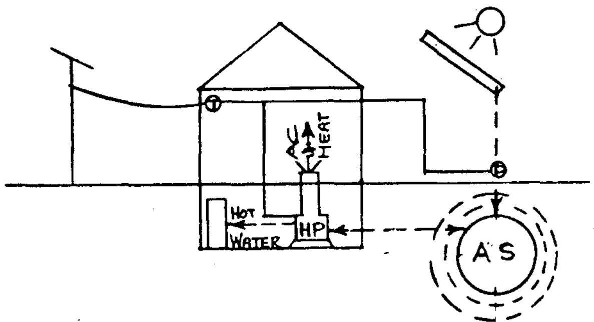
Figure C-3 - Some Conventional and Solar Heating System Configurations



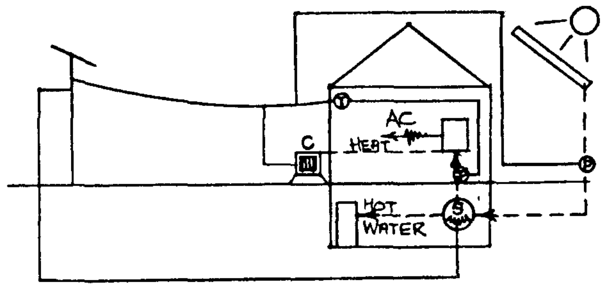
5. SOLAR SPACE AND WATER HEATING, 1 DAY STORAGE, 60% SOLAR UTILIZATION, HEAT PUMP AND ELECTRIC RESISTANCE BACKUP



6. SOLAR SPACE AND WATER HEATING (FLUID OR AIR COLLECTORS), 1 DAY STORAGE, 60% SOLAR UTILIZATION, HEAT PUMP AND OIL HEAT BACKUP



7. SOLAR ASSISTED HEAT PUMP FOR SPACE AND WATER HEATING ANNUAL STORAGE, 70% SOLAR UTILIZATION (NO BACKUP REQUIRED).



8. SOLAR SPACE AND WATER HEATING, ELECTRIC HEATED STORAGE BACKUP, 60% SOLAR UTILIZATION, ELECTRIC AIR-CONDITIONING, OFF-PEAK CHARGING OF THERMAL STORAGE

Figure C-3 - (Continued)

System 2 represents an increasingly common type. It employs an air-to-air heat pump for heating and cooling, with electric resistance heating used for water heating and for backup on days when the heat pump cannot supply the total thermal load. Note that at such times, System 2 must rely on its resistance backup and, therefore, imposes the same peak demand as System 1. However, in some parts of the country this would occur at night and would not present a severe problem to a day-peaking utility. When the heat pump is operating, its higher efficiency results in lower total energy use and thus in a lower customer load factor - about half that of System 1.*

System 3 includes solar collection designed to furnish 60% of the annual space and water heating requirement, and electrical air-conditioning, with electric resistance space and water heating backup. Since it must rely on electric heat for backup during extended periods of cold, cloudy weather, it imposes a peak demand equal to that of System 1. But the energy collected from the sun is not required from the utility; the resulting customer load factor is slightly less than for System 2.

System 4 is a variant of System 3 which uses oil heat for space and water heating backup. Because electricity is no longer required to supply these loads--dominated by air-conditioning--the peak demand is considerably less, on the order of 8 to 9 kw. The load factor will depend on whether air or liquid is used as the solar collection medium, principally because the energy required to pump air through a crushed-rock storage unit is greater than the energy required to pump liquid through a thermal storage tank. The customer load factor for the air collection system is about the same as for System 3; if liquid collectors are used, the load factor is about 20% lower.

System 5 illustrates a system similar to System 3, but with an auxiliary heat pump for backup instead of electric resistance heating. As in System 2, the heat pump does not supply the total heating load when the outside air temperature is too low, so an electric resistance backup is still required, and the peak demand is the same as for System 1. Indeed, the solar collectors supply the heat during much of the time that the heat pump would be operated, and the customer load factor is not significantly different from System 3. Such a system may have a lower first cost than a conventional solar system if air-conditioning is required.

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* The peak demands and load factors discussed in this section are approximate; being based on some measured data from the Project Phoenix house, other data derived from manufacturers' specification sheets, and some engineering estimates. Their intent is to provide a framework for discussing the interactions of system load characteristics and utility rates; they are not a reliable basis for system comparisons or other purposes.

System 6 is a variant of System 5 with an oil burner supplying backup heat for space and water heating. It imposes a peak demand similar to System 4, and has a higher load factor, though not as high as System 1.

Systems 3 through 6 are assumed to include thermal energy storage capacity for 1 day. System 7 employs a solar-assisted fluid-to-air heat pump with a very large, buried thermal energy storage tank sufficient for an entire heating or cooling season. This concept, known as annual storage, allows the heat pump to operate between more favorable temperature limits. This imposes roughly the same peak demand as Systems 4 and 6, but uses more electrical energy, and has a load factor slightly greater than System 1, by perhaps 10%.

System 8, like System 3, uses electrically heated storage for backup, but limits its peak demand to 20 kw. Peak shaving is accomplished through predictive thermal storage as proposed by Petersen in Reference 15. Because of this peak shaving, the load factor is improved by perhaps 50% as compared to System 3. It should be borne in mind that some energy is lost from the storage system - perhaps 5% of the amount stored - and that these losses must be included in considering the effects of thermal energy storage.

4. Implications relative to solar systems with electric backup

- Public utilities must design their systems for complete backup of solar systems until enough experience is accumulated to accurately predict diversity and peak coincidence.

- Unless storage of thermal energy for backup use is a specific objective of the design, solar-heated houses present unfavorable load factors from a utility viewpoint.

- The accuracy of existing computer simulations is limited by a scarcity of required input data. Collection of insolation, weather, and system performance data on existing installations would help to calibrate the computer simulations and would allow better analysis of load factors and possibilities of coincidence of the backup demand with the utility's peak period.

D. Distributed Energy Collection

Issue 4: How does the distributed, intermittent nature of the energy sources of consumer-owned, wind-powered systems (including both electric generators and direct heating systems) affect the economics of their interface with the utility?

Assessment: Distributed wind energy collection systems used for direct heating and cooling or generation of electricity, present economic problems of utility demand and load factor similar to those of solar energy systems. The low customer load factor may be further affected by distributed wind energy systems if such systems, in their electric power generation mode, feed surplus power back into the utility grid or if some form of energy storage is used at the load site. Wind energy systems also present some technical problems of system safety and transient control, but these can usually be solved by proper attention in equipment design. Wind energy collectors differ from solar energy collectors--including photovoltaic collectors--in being able to supply energy at night as well as by day. Also, seasonal variations in wind energy are expected to follow heating loads more closely than seasonal variations in insolation. Thus, the nature and performance characteristics of distributed solar and wind energy systems are expected to have similar but somewhat different impacts on the required utility rates needed to achieve rate structure equity for such systems.

1. Wind energy collection systems are similar to solar heating systems in presenting a backup demand that has a low load factor: The utility has the obligation to provide reliable service, and in the United States, consumers have come to expect service on demand. Wind and solar energy collectors, however, produce energy only when the wind blows or the sun shines. Unless the wind system incorporates energy storage, the utility must provide generation, transmission, and distribution capacity for the full load, but sells only the backup energy, thus incurring a low load factor. Load factor is important in the utility's cost of service, and, in turn, in the rate structure, as discussed under Issue 2.

The impact of interconnected wind-energy systems will depend on the actual character of the wind-energy backup demand and excess production available form the wind generators, just as the solar impact depends on the character of the solar backup demand.

2. Wind energy systems may present safety and other problems of systems integration: Consolidated Edison Company of New York recently confronted a consumer group that owns a wind generator and seeks to interconnect with the utility to receive credit for any surplus power the wind generator can produce. Citing provisions in its tariff and other arguments, Consolidated Edison Company asserted:11/

- Consumer power generation poses a safety hazard since the company cannot ensure that power is off its distribution network during maintenance and repair periods.

- Interfacing and control equipment for the distributed wind generators might introduce harmonics and transients into the system.

- It is not economic for Consolidated Edison to purchase power in units of less than 2.5 megawatts capacity, and then only if the power is available on demand.

The first of these problems can be solved by including a switch in the synchronous inverter that disconnects the wind generator when the utility power is cut off. This feature is incorporated in one wind system now in use in over 20 areas where wind generators are tied in with utility grids.

The second problem has been analyzed by G.E., Westinghouse and others. The required degree of smoothing is still under study; if very strict standards are imposed the cost of distributed generating equipment could become prohibitive. Transients should not present an insoluble problem if the capacities of the distributed wind generators do not exceed 10% of the capacity of the utility grid.

The third issue is complex, and involves all the effects on utility load factor addressed in the previous section. It cannot be resolved without more data on the performance of wind energy systems. Regulatory action will probably be required to resolve the fundamental principles involved.

3. <u>Differences in the seasonal availability of wind and solar energy will produce differences in the demands for utility backup of such systems</u>: The energy demand for heating purposes is, of course, greater in the winter season than in the summertime. The available wind power density is usually two or three times greater in wintertime than in summertime at most sites. On the other hand, the solar power density is usually two or three times less in wintertime than in summertime at such sites. Since the availability of wind energy is expected to provide a better match for heating loads than the availability of solar energy, this may more than compensate for any differences in the costs per unit collector areas for wind and solar energy systems, and also should result in lower load factors for wind backup systems.

In addition, buildings cool more rapidly when the wind is blowing, yet wind energy is available at such times to generate heat for these buildings. This will also tend to lower the load factor for wind energy backup systems.

In contrast, solar energy cooling systems should provide a better match for cooling loads, resulting in smaller utility system backup load factors for such applications.

Moreover, the addition of local energy storage capabilities at the load site would be expected to reduce the customer backup load factor in any of the above applications.

4. Combination wind and solar collection systems will further reduce load factors of backup systems: Wind energy systems are being developed that pump hydraulic fluids to high pressures to produce either direct thermal energy through the use of a friction orifice, or to drive a heat pump without conversion to electrical energy. Such wind systems are analogous to direct solar thermal collectors. Likewise, wind energy systems that generate electricity are analogous to solar photovoltaic collectors.

Since wind and solar availabilities exhibit different characteristics, systems that use combination wind and solar collectors, either for direct heating applications or for generation of electricity, are expected to reduce both short-term and seasonal variations in available energy inputs, thereby decreasing both the requirements for common energy storage at the load site, as well as the load factor of any utility backup system that is utilized.

Further studies are needed to determine the optimum trade-offs between the use of combination wind and solar collectors, energy storage systems at the load site, energy storage systems at the utility central power generation site, and the use of demand capacity facilities for utility backup of distributed wind and solar energy systems. Such studies can also supply supporting data for determining equitable rate structures for such applications.

E. Backup Systems

Issue 5: Should the nature of backup energy sources for solar and wind energy systems be influenced by state and municipal government or regulatory agencies? If so, what is the best means for such influence?

Assessment: Energy and demand costs will vary for each electric utility and region of the country because of differences in existing generating mix, fuel cost, transmission and distribution cost, and other factors. The cost and performance of various solar and wind system configurations similarly show considerable differences from region to region, and are likely to change with time as solar and wind energy collection and thermal or other energy storage technologies improve. The designer of solar and wind energy systems should be free to choose among backup energy systems, energy storage designs, and storage management schemes. If his choice is influenced by electric rate structures that accurately track the cost of providing service, he will be drawn toward configurations that minimize the combined cost to the homeowner and utility of energy supply.

Backup energy sources for solar and wind energy systems should be influenced to minimize total combined costs of the user and the utility. If strict, legal restrictions are avoided and influence is through utility rate structures that accurately reflect the costs of providing backup service, then solar and wind system designs can be expected to converge on configurations that optimize total energy costs.

1. Artificial constraints on backup energy systems are likely to have undesirable results: If the utility wishes to avoid serving low load factor customers, it conceivably might seek to bar connection of solar and wind energy backup systems to its facilities under its tariff. This could be undesirable because most solar and wind energy systems are already costly, and the alternatives to electric resistance heat--oil and gas--are generally more costly in terms of capital expense, and one or both may be unavailable in some regions.*

An alternative is to allow solar and wind energy systems to install electric backup under rate structures that accurately reflect the utility's cost of service. Such rates would tend to lead solar and wind system designers to include thermal energy storage, interruptible backup systems, improved energy conversion measures, mixed solar and wind energy collection systems, and other features that will reduce the reliance on electric backup and will improve the backup load factor. Because this alternative leads naturally to improved system design and better overall economic performance, it is preferable to a rigid exclusion by provisions of a tariff.

2. Backup heat supply alternatives: As the configurations of Figure C-3 illustrate, electric resistance heat is only one of a number of possible sources of backup heat to a solar heating system.

Most existing solar heating systems rely upon electric resistance backup because of its perceived convenience, favorable economics and high reliability. Most solar system designers and potential owners think first of electric backup energy, and only secondarily consider other types of backup such as oil and gas. Some solar design plans have been cancelled when it was found that electric backup either is not available from the local utility, or that it would be too expensive to justify.

Oil can be an ideal energy storage medium: it provides a high energy density, modest storage costs and is widely available. Gas, where already available, may provide a comparatively low cost backup energy alternative for some applications. Even bottled gas should not be overlooked in seeking feasible alternatives to optimize designs of solar heating systems.

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* In return for this higher initial cost, the direct combustion of oil and gas to provide backup heat may result in a higher energy efficiency than does electric resistance heat, in utility systems where electricity is produced by burning oil or gas at a power station and transmitting it for miles to the point of use. The efficiency of direct combustion of oil or gas in residential heating unit ranges from 60 to 70%. After combustion, generation, and transmission losses are sustained, the energy efficiency for electric resistance backup is on the order of 30 to 35%.

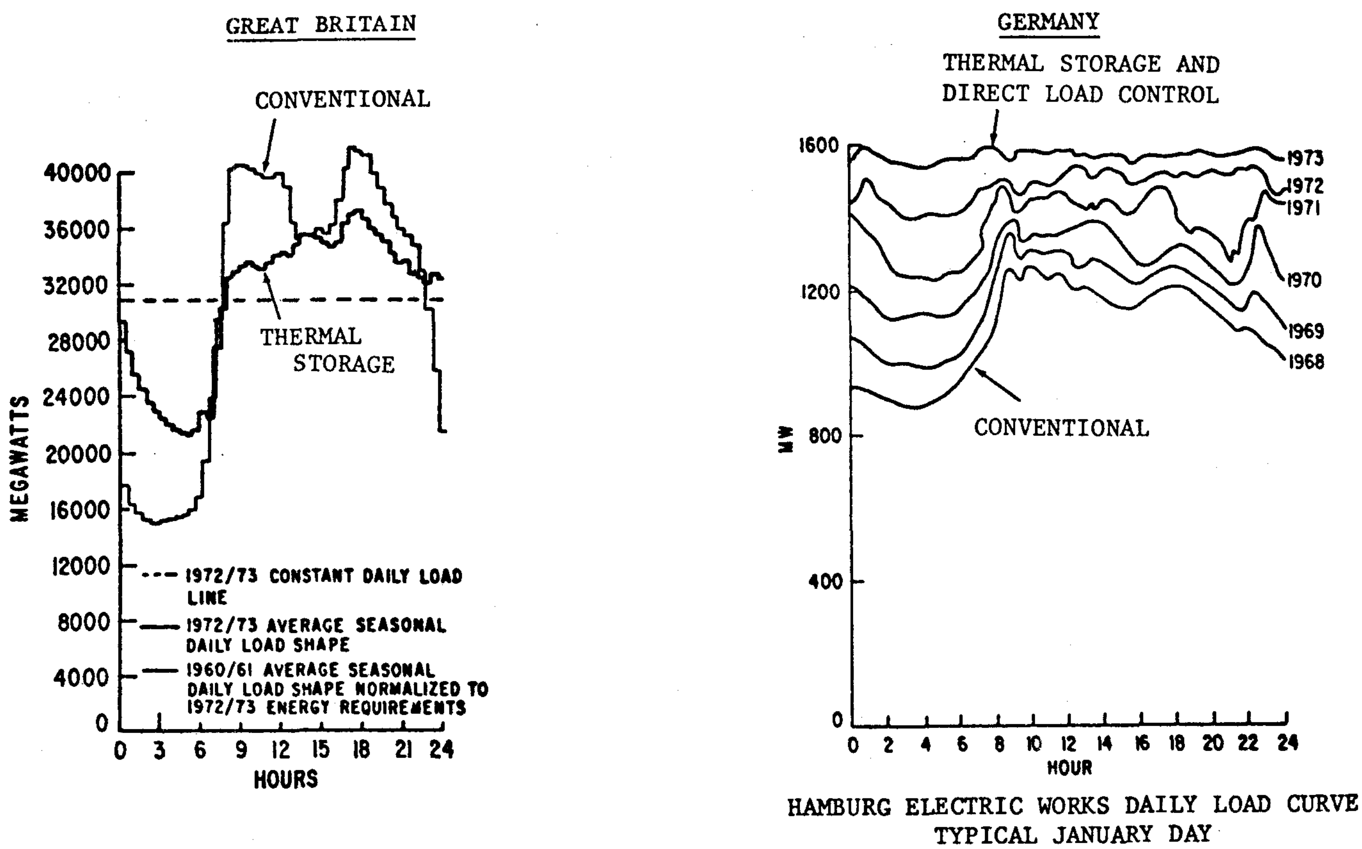
Additional capital costs are usually associated with these alternate backup approaches. However, the major consideration in selecting a final design should be a total life cycle cost, and to the extent that non-electric backup energy systems are cost-effective, the economics would dictate that they should be considered.

3. Thermal energy storage (TES): Solar systems require thermal storage on at least a daily basis. The inclusion of thermal energy storage modules affords the designer the opportunity to improve his backup energy load factor by drawing energy at off-peak periods. Petersen (Reference 6) gives an example where a solar system could limit its peak-period demand on the utility to two-thirds that of the peak demand of an electric resistance heating system by charging its thermal storage during the preceding off-peak periods. His example assumes utility company control of the thermal storage based upon short-term predictions about available insolation and expected minimum temperatures.

a. Daily load factor improvement with thermal energy storage: Thermal energy storage space-heating systems are already in wide use in Europe, and have improved the winter daily load curves as illustrated in the following figures. The flattening of the load curve is much more dramatic for the German City of Hamburg because the power company directly controls the time when the storage units are allowed to draw electric energy, and the storage units themselves are divided into two types to achieve further smoothing of the daily load curve. The British load curve shows less improvement because only one type of storage unit is used, and the power company does not employ direct control of connection times. The British system incorporated peak load pricing in the rate structure, and the units are timed to switch on at the end of the peak period.

b. Thermal energy storage technology is available now: In its study for the Electric Power Research Institute,[14] A. D. Little concludes that load management via off-peak thermal energy storage affords substantial cost saving opportunities for utilities and solar users. A. D. Little also points out[15] that solar systems are cost-effective where the cost of electrical energy is high, while thermal energy storage systems are cost-effective where the cost variation with diurnal load is high:

Cost Variation of Electrical Supply with Diurnal Load	Cost of Electrical Supply: Low	Cost of Electrical Supply: High
Small	Favors Conventional Systems	Favors Solar Collection
Large	Favors Off-Peak Storage of Thermal Energy	Favors Solar Collection Plus Off-Peak Storage of Thermal Energy



SOURCE: Joseph G. Asbury and A. Kouvalis, Electric Storage Heating: The Experience in England and Wales and in the Federal Republic of Germany, Argonne National Laboratory, ANL/ES-50, May 1976.

Figure C-4 - Backup Systems Daily Load Factor Improvement With Thermal Energy Storage

Where electrical fuel costs are high and the cost of electricity varies sharply with demand due to high-cost peak generating facilities, both solar and thermal energy storage will be economically advantageous. If peak electricity costs are substantially the same as off-peak costs, then there is little point in providing thermal storage. If the overall cost of electricity is low, then the capital investment in solar collection equipment is hard to recover; the chief value of solar energy in that case being in diversion from non-renewable fuel sources.

It should be noted that there are limits to the benefits that accrue from higher load factors. Utilities take advantage of the off-peak period to perform routine and preventive maintenance on their equipment. If the load curve is perfectly flat, reserve capacity must be installed to allow some units to be taken out of service for such maintenance.[4/] In addition, because of the essential nature of electric service, reserve capacity must be maintained for situations when unusual weather conditions or other emergencies may place unexpected peak demands on the utility.

F. Utility Ownership of Solar Heating Systems

Issue 6: Should utilities participate in the supply or ownership of solar heating systems?

Assessment: Utility ownership of heating systems is not a common pattern in the heating and utility industries. However, utility ownership offers several potential economic advantages to consumers that would encourage the introduction of solar heating systems. Utility participation should be regulated (within existing regulatory structures) to avoid creating cross-subsidies or unfair competition with other heating system types.

1. Utility ownership of solar heating systems does not correspond to the traditional patterns of the utility and heating industries

Legal Tradition: The utilities' tradition and legal precedents are to provide reliable service at the customer's property line. The owner conveys the service on his property; he also owns, operates, and maintains the heating equipment and other appliances.

This pattern has the advantage of providing an easily-defined interface to separate the liabilities of the owner from those of the utility. Such separation is important because a gas leak or short-circuit can readily cause property damage, injury, or death.

Industry Pattern: The heating and cooling industries are competitive, and the installation and service portions are fragmented and highly competitive. Utilities, of course, are regulated natural monopolies.

2. Private owners of solar heating systems face high initial costs: On a life-cycle cost basis, solar heating systems are already attractive in many instances. Based on comparison with conventional energy costs, solar water heating and solar space heating installed at an equivalent system cost of $20 per square foot of collector is competitive today against electric resistance systems throughout most of the U.S. If the system cost is reduced to $15 per square foot solar systems become competitive against oil hot water heating and/or oil and electric heat pump space heating in many cities. Finally, if the cost should be reduced to $10 per square foot by 1980 through a combination of technical innovations and incentives, solar hot water and heat would be economically competitive against all fuel types.[18/]

But the primary concern of a home buyer is often on the initial cost, and the payback periods are inclined to be lengthy. (The criterion of economic competitiveness adopted in Bennington's analysis is the occurrence of positive savings within 5 years or payback of initial investment in 15 years or less.) A home buyer with limited capital resources may be unable to take advantage of lower life-cycle costs, even if he believes that they exist.

3. Utility ownership of solar heating and distributed wind energy systems offers some potential economic benefits

- The utility could achieve economies of scale through large-volume purchases and by building shared collection and storage facilities for a number of users. If individuals purchase units, additional costs arise due to distributor and dealer markups, and units may cost significantly more than if the utility purchased them directly.

- Solar and wind energy would no longer represent competition to the utility, since it would be selling heat rather than electricity or gas. It would be in position to optimize the economic trade-off between solar and backup energy supply.*

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* Many home buyers do not specify the quality of their space and hot-water heating systems. Those who do may have inadequate information or experience on which to make a purchase decision that minimizes life-cycle cost. The utility is better equipped to acquire and evaluate such information, which can include its own maintenance records.

- The homeowner would pay for maintenance as a constant part of his heating bill, and avoid exposure to intermittent, sometimes costly, maintenance bills. The utility, in turn, would design its systems to optimize the trade-off between first cost and maintenance cost, thus minimizing life-cycle cost.

4. Utility ownership of distributed solar and wind energy systems could entail some undesirable economic effects

- Because of its vertical integration and ownership of the means of energy supply, a utility could assume a position of unfair competition with other types of heating systems. If a utility participates both in the manufacture and ownership of distributed solar or wind energy systems, it might seek to allocate costs away from manufacturing toward other operations, thereby securing an unfair advantage in manufacturing cost and undercutting the position of competitive solar equipment manufacturers.

- Rate structures would require careful attention to avoid cross-subsidies with other uses of electrical energy. Rates might fail to track costs if the rate structure fails to recognize all the costs incurred in supplying and maintaining heating equipment. Since the overall regulation of utilities requires that they recover all of their cost of service, improper cost accounting could lead to heating customers being subsidized by lighting customers or vice versa.

- Utility-owned solar generation equipment, whether central or distributed, presents the problem of what its optimum proportion should be in the utility's mix of generating equipment. In studying the problem of utility production of solar energy, Peterson concludes that the utility, being regulated on return on invested capital, would tend to be generally favorable to the inclusion of more capital-intensive capacity in its generation mix than would be dictated by a socially optimum allocation of resources.[19] This would apply to solar heating equipment as well. The evaluation of social optimality in this context must include a valuation of energy diversion to nonrenewable resources.

- A number of small solar businessmen and entrepreneurs are worried that if the utilities become the primary dispersers of solar equipment, they will tend to turn only to the more well-known solar manufacturers that produce the bulk of the square footage in the marketplace. These large manufacturers are the ones that can usually offer the most comprehensive warranties and that can produce the quantities the utilities may need, but they are not necessarily the ones with the best systems by any means. To the extent this is the case, small businessmen will be forced out of the market. Without special provisions for the protection of small businessmen, they may have difficulty staying in the solar market.

G. Potential for Oil Savings

Issue 7: What government action is appropriate to encourage the conservation of oil and gas through increased use of solar and wind energy?

Assessment: From a national perspective, there are advantages in the conservation of nonrenewable resources, particularly oil and gas. The impact of solar and wind energy on oil conservation is complex, and solar and wind systems are difficult to justify solely on short-term economic grounds, although long-term economic considerations may be favorable.

1. The advantages of solar energy use are best seen from a national viewpoint

- Conservation of nonrenewable fossil and nuclear resources is essential to maintaining our living standard, because oil has unique advantages as a transportation fuel, and because both oil and gas are valuable as chemical feedstocks.
- Increasing dependence on foreign oil and gas poses potentially severe economic problems to the nation.
- Energy independence is an important factor in national security.

Analyses of solar heating economics have tended to neglect the value to the nation of nonrenewable fuel conservation, probably due to the difficulty of putting a price on the diversion of energy production from fossil fuels to the solar source.

Even though some solar applications may be justified on a long-term economic basis, the homeowner may be deterred from installing a solar system because of the high initial cost, particularly in view of the required investment in a backup heat source.

From the point of view of the utility, the energy collected from the sun is energy it cannot sell and collect revenue on, reducing the rate of return on the facilities it must install to provide backup.

It is clear that the value of energy diversion is hard to include in economic assessments of solar heating system introduction. A closely related problem--how to estimate how much diversion will actually occur--is discussed in the following section.

2. How much fossil and nuclear fuel can solar and TES systems be expected to save?: The studies of potential oil savings indicate that oil savings are uncertain, and likely to depend on the details of each individual utility. In assessing oil savings from thermal energy storage systems, Asbury et al. conclude[20] "An unexpected finding is that in some service areas TES systems will have little effect on long-run utility oil consumption . . . changes in utility oil consumption are very sensitive to the outputs of oil- and coal- (or nuclear) fired generating plant. In many utility service areas, a more important oil savings will occur as a result of the displacement of oil and natural gas from end-use markets."

The latter conclusion rests on an argument involving a kink in the utility's load duration curve in the vicinity of the point of cost equilibrium between base and peak generating facilities. In brief, the report says that thermal energy storage systems reduce demands during peak periods, but tend to increase demand in the time periods adjacent to the peaks. The result is to shift load across the kink in the load duration curve so that, while the overall capacity requirement may be reduced, the total amount of energy supplied by oil-fired generating plants may be increased. The existence and location of such a kink would depend on:

- The nature of TES systems and whether the utility employed direct load control via telemetry.
- The existing generating mix of the utility.
- Other contributors to the total utility load.

Asbury and Mueller indicate that for the most part, solar energy displaces off-peak energy that is mainly coal and nuclear. The real savings of oil and gas occur on the customer side through substitution of solar energy systems for oil or gas-fired systems.

II. OPTIONS FOR GOVERNMENT ENCOURAGEMENT OF SOLAR ENERGY SYSTEMS

Government efforts to encourage solar heating and cooling systems fall into two classes, depending on whether they take the form of cost reduction or subsidy:

1. Efforts to reduce costs and improve the competitive economic position of solar systems by research and development efforts, early and expanded use of solar energy in federally owned buildings, training of installation and service personnel in new methods, education of builders and the public about the technology of solar systems, proposals of model building codes, and encouragement of the development of voluntary standards for solar equipment.

- Such efforts are easily reduced when their need--or productivity--declines.
- Adoption of solar energy in federal buildings facilitates the development of a solar industry infrastructure.

2. Efforts to offset the economic disadvantage by subsidies in the rate structure.

- Such efforts tend to reduce the incentive to develop more cost-competitive solar and wind energy systems.
- They tend to become embedded in the institutional structure and may be difficult to remove when no longer needed.
- They tend toward relatively less efficient economic performance from an overall, national viewpoint.

Examination of these issues suggests seven possible actions:

1. For utilities where solar systems pose utility load factor problems, public utility regulatory bodies should consider adopting time-of-use and load management contract rate structures designed to reflect total costs of power generation and distribution.

Since such rate structures can accurately reflect the utility's cost-to-serve, they would tend to encourage configurations, both novel and conventional, that minimize total energy costs. In addition, such rates will help ensure that trade-off decisions between solar and wind energy systems and conventional systems will be economically rational.

2. Where regulatory commissions prefer to retain traditional rate structures, separate, cost-tracking schedules may be applied for customers using solar and wind energy systems.

A customer using a solar or wind energy system may present a lower load factor and possibly a different time-of-demand curve to the utility than does either a non-heating or electric heating customer. Because this difference in customer load factor and time of demand raises the demand-related proportion of the cost of the backup system required to serve him, rates based on conventional customer load factors do not necessarily result in equitable charges for solar and wind system customers. Conventionally-constructed rates tend to subsidize the solar and/or wind customer by charging him less than the utility's actual cost of providing service. Rates that charge separately for peak demand and energy are more flexible, but need to address whether demand is greatest during the utility's peak load period. Demand-plus-energy rates will fail to track for a customer when the customer's peak demand occurs at a different time from the utility's peak demand period.

3. Equitable reform of rate structures requires data on the load factor imposed by the solar and/or wind backup demand and on its time correlation with other system loads. Federal solar energy demonstrations and data on a significant sample of each type of existing solar and wind heating and cooling installation and wind electric power generation system.

Data should be collected on a uniform basis to allow direct comparability among system types and with conventionally heated buildings and conventional means of generating electricity.

A related, useful action might be for state regulatory bodies to request utilities to submit proposed schedules for solar heating backup service, which could then be publicly reviewed in hearings before final acceptance. Such a procedure would help develop the detailed information needed for eventual rate-making action.

4. Studies and demonstrations should be undertaken to determine seasonal variations in heating and cooling loads in various geographical locations of the U.S. and how they correspond to seasonal and short-term variations of solar and wind energy in those locations.

These data, together with cost estimates of solar, wind, and conventional energy systems, can be used to determine optimum trade-offs in the use of solar and wind energy collectors (and combinations thereof), the use of energy storage systems at the load site, and the use of utility facilities for backup. On this basis, the effects of various rate structures on solar and wind energy systems can be determined.

5. The nature and sizing of backup energy sources for solar and wind energy systems should be allowed to optimize naturally under a rate structure that accurately reflects cost of service as discussed in recommendations 1 and 2.

6. Regulatory agencies should consider permitting public utilities to participate in the manufacture, ownership, or supply of solar heating systems after weighing the possible economic benefits and the potential for encouraging the introduction of solar technology.

Such activity would have to be carefully regulated to avoid unfair competition with other suppliers of heating systems and to avoid cross-subsidies with other electric users.

7. The federal government may wish to encourage the use of distributed solar and wind energy systems which hold promise of achieving economic viability for heating and cooling and generation of electricity through: (1) its research, development, and demonstration program, and (2) by commercialization activities aimed at strengthening the industry infrastructure and encouraging informed consumer demand.

One important objective of the Research, Development, and Demonstration Program should be to reduce the cost of both manufacturing and installing solar heating and cooling capacity. Other areas for federal government action could include training and education programs for trade craftsmen, builders and consumers, proposals of model building codes for adoption by communities, publication of information on optimum system configurations and operating modes, and encouraging the development of voluntary standards for solar equipment. In addition, the federal government should consider commercialization programs such as the early, expanded use of solar energy infrastructure and thus lead to improved solar cost effectiveness. The government can assist solar and wind energy RD&D to reduce system costs and by other measures such as educational programs and model building codes.

In addition, subsidies may be deemed appropriate as a policy decision to achieve the societal benefits obtainable from an accelerated shift to solar energy if such a shift would not be achieved as a result of individuals acting in their own economic self-interest. While distorted rate structures conceivably could provide such a "subsidy," they would lead to a relatively less efficient economic performance from an overall national viewpoint and would reduce incentives for improve cost effectiveness of solar and wind energy systems. Other, more visible and direct forms of subsidy should be considered as alternatives if subsidies are deemed necessary as a matter of policy.

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APPENDIX D

DESCRIPTION OF THE COMPUTER MODEL

APPENDIX D

DESCRIPTION OF THE COMPUTER MODEL

TABLE OF CONTENTS

I. INTRODUCTION

The FEA/ADL solar energy market penetration model is designed to gauge the impacts of selected federal incentive programs to encourage the development of solar energy equipment for hot water heating, space heating and air conditioning in residential and commercial buildings.

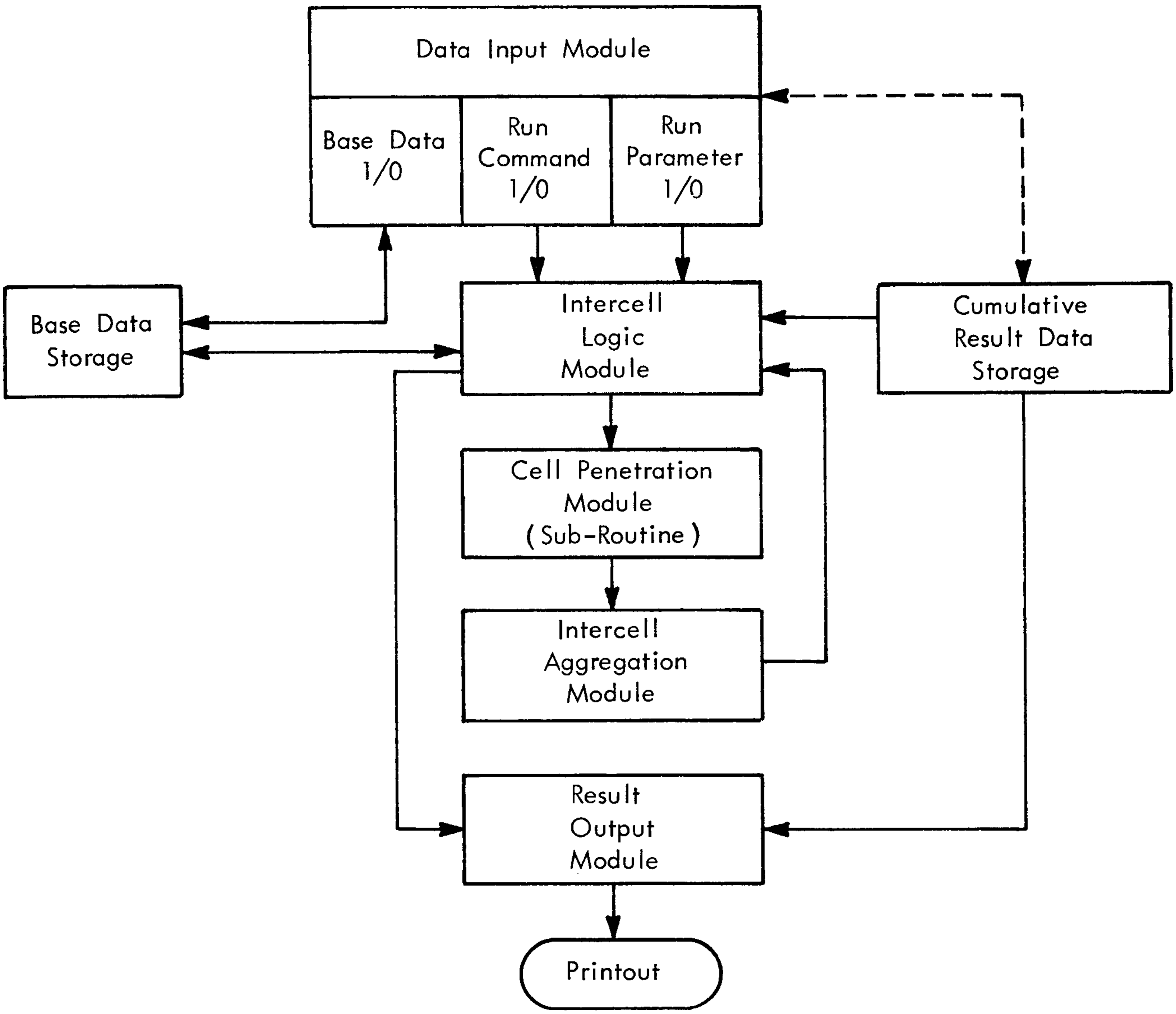
In this brief description of the model, both the model structure and the nature of its specific components will be discussed. The following two sections discuss market penetration curves and experience effects, respectively. Section IV identifies limitations of the model, followed in Section V by a discussion of the application of the model. The appendix concludes with a review of input assumptions.

The model is designed to run with ten (10) different categories of market/building types; for the ten (10) FEA regions; for the fourteen (14) year period of 1977 to 1990.

Figure D-1 is a block diagram of overall structure of the impact model computer program. The program is designed as a series of interacting modules, comprised of sub-routines, each serving a specific function. At the heart of the model is the cell penetration module, within which the market penetration for solar energy devices are calculated for each particular year, market and building type and region. A large portion of the logic associated with the important market variables resides in the penetration module.

The model requires a large amount of data in order to run. Much of the required data are building market and fuel price projections over the 1977 to 1990 time frame. Generally these types of data will not change from run to run and are entered onto a large data file maintained under the WYLBUR file system. Other data required to execute the program include command and parameter inputs. Command inputs direct the model to be executed for various regions, years and markets. Command inputs also indicate which federal incentives will be considered.

Parameter inputs include the levels of the incentive programs (tax credit percentage, investment limits, etc.) and other parameters relating to the weighting or importance of certain effects in the model. In the model these parameters are either reset for each computer run or are defaulted to values already within the data base.



Source: A. D. Little, Inc.

Figure D-1 - FEA/ADL Solar Building Technology Penetration Model Substructure

The separate penetration cells (region by market/building type by year) are linked together by the Intercell Modules. Within the computer program these modules preprocess the data used within the Cell Penetration Model such as the solar device costs and the individual market response functions or penetration curves. The results of the Cell Penetration Module are aggregated by the Intercell Modules in order to accumulate total solar device experience which is used to influence both production costs and market behavior.

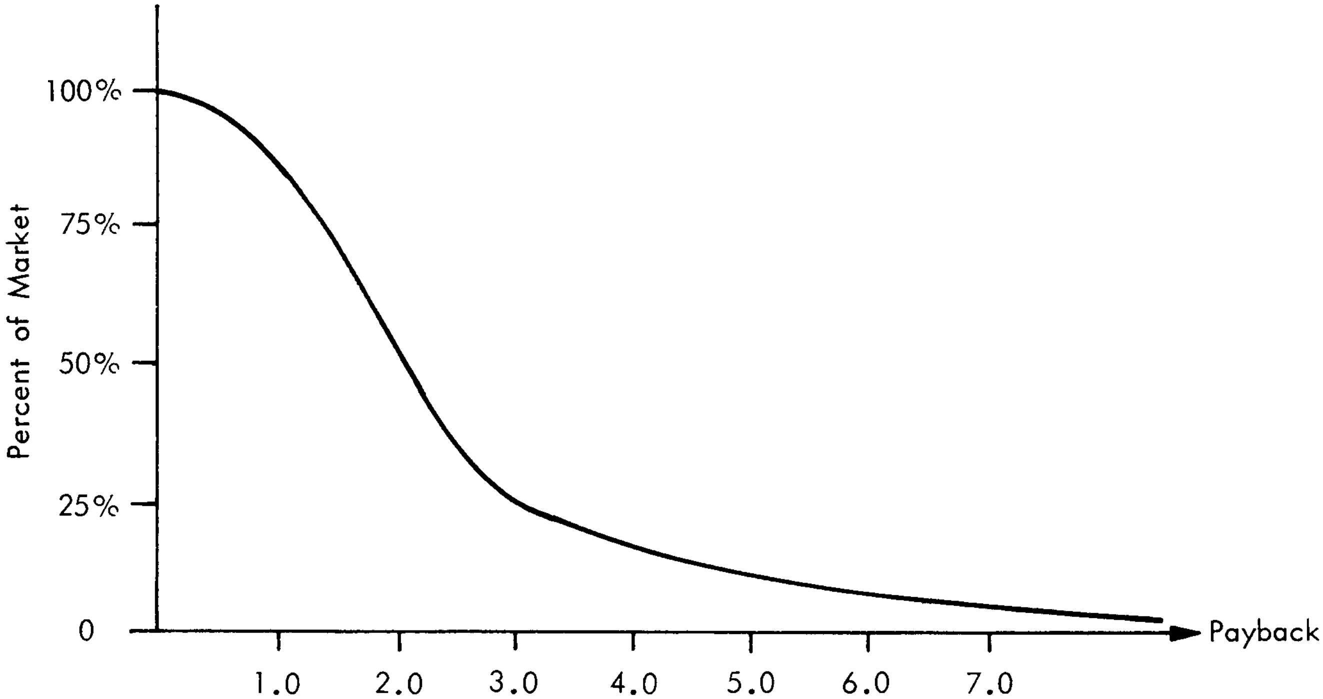
During execution of the model the important results such as the energy saved, the square feet of collector installed, the cost to government and other results are aggregated for summary printout at the end of execution.

II. PENETRATION CURVES

The central component upon which the solar device impacts are estimated, is the penetration curve. The penetration curve is a market-oriented response function which relates the percentage of building/market type decisions in which a solar device will be chosen for installation. The major independent variable is the financial parameter of undiscounted device payback period. Payback is simply the ratio of device installed first-cost to net annual cost savings associated with the device. Figure D-2 represents a typical penetration function expressed in relation to payback. The penetration curve of Figure D-2 indicates that with a 2.0-year payback period, in 50% of the situations where solar device could be chosen, it would be.

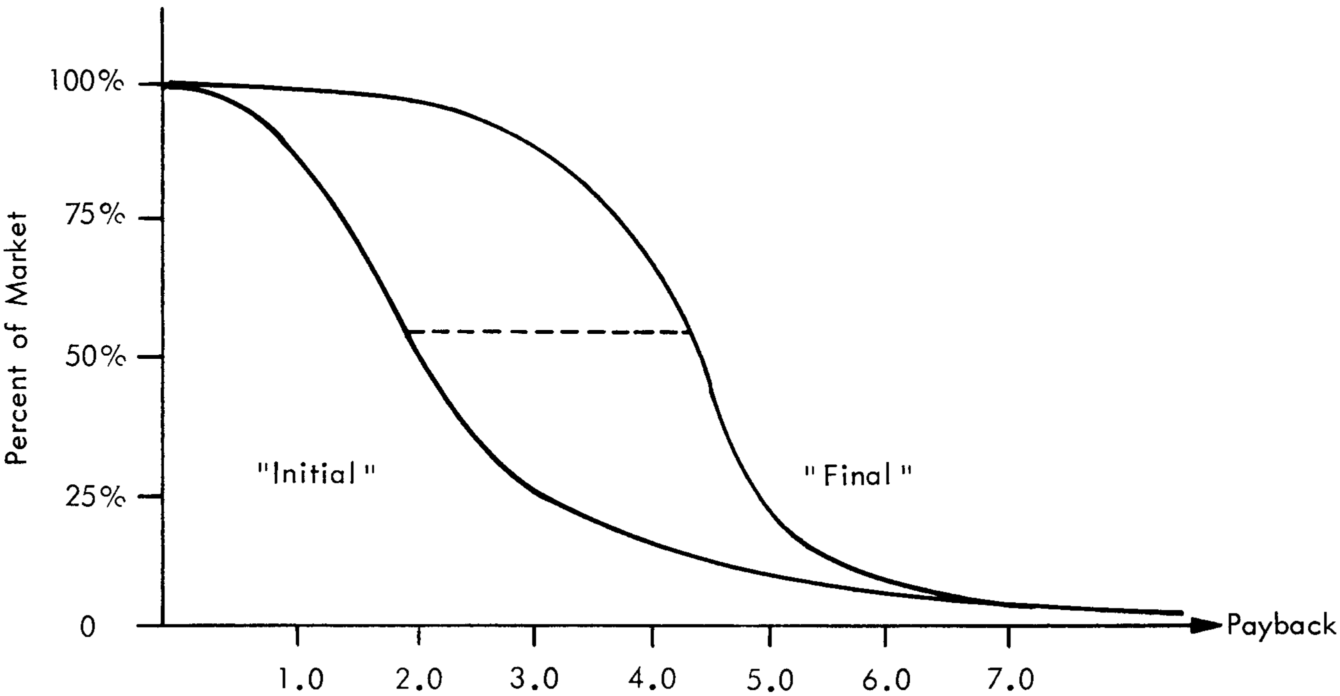
The development of a market penetration curve is ultimately an empirical task. Available data are not adequate to construct a market penetration curve for most building sectors mainly because the exposure to solar energy technology has been small. Curves can only be developed from historical information and so will never directly apply to estimating market response in the future. For this reason market penetration curves are theoretically postulated.

The basis for postulation of the penetration curves is involved with the spectrum of rates-of-return on investment deemed necessary by the particular class of decision-makers in that market. The rate-of-return expected generally will be higher in situations where the technology is not well-proven within that building/market type and the decision-makers have little or no experience with solar energy devices. Many individuals will shy away from solar energy and require large rates-of-return on their investment to pursuade them to decide in favor of solar energy. Figure D-3 indicates two separate market penetration curves. The curve on the left is



Source: A. D. Little, Inc.

Figure D-2 - FEA/ADL Penetration Curve



Source: A. D. Little, Inc.

Figure D-3 - FEA/ADL Penetration Curve, "Final" and "Initial" Configurations the initial or low experience level curve whereas the curve on the right is the final or high experience level curve. The initial curve represents the penetration curve in effect when solar energy experience is low. As experience increases, the effective curve tends toward the final curve of Figure D-3.

From the point-of-view of economics the final curve is the economically rational curve; the initial curve reflects a highly uneconomic point-of-view. The shape of these curves will vary among market sectors and as a function of time.

Penetration is not only affected by the financial performance of the solar devices. In addition to their financial attributes, solar devices have characteristics which are non-financial in nature and rate their ability to fulfill ancillary, secondary functions. These non-financial characteristics include the device esthetics, space requirements, reliability (from a non-financial point-of-view), non-polluting nature, noise and convenience.

Decision-makers in different market sectors give different weighting or importance to the range of solar device characteristics-- both financial and non-financial. For any market sector the importance of the decision-makers within the decision must also be considered. The classes of decision-makers which may be important to the decision include the developer, owner, architect/engineer, bank officer, municipal official, etc. By mapping the decision-maker's characteristic weights against the decision-maker's weight in the decision, the importance of each characteristic of the device is rated as a percentage of the total.

In the penetration logic it is postulated that non-financial characteristics can affect the penetration of solar devices. The mechanism for effecting this influence is to establish a trade-off between the financial variable of payback, PB and the composite weighted rating of the non-financial characteristics referred to as the non-financial utility, UTIL. The rating of each non-financial characteristic can vary between ± 1.0; a level of 0.0 implies a level equivalent to conventional systems. A +1.0 indicates the highest level that characteristic could attain; whereas, a -1.0 indicates the worst possible level. Because $\frac{1}{PB}$ = FOM (figure-of-merit) ranges from a level of 1.0 (or more if PB < 1.0) down to 0.0 (as PB goes to $+\infty$), the UTIL value is used to adjust or trade-off $\frac{1}{PB}$ and UTIL. If W_{PB} is the relative weighting of PB (and $\left[1-W_{PB}\right]$ is the relative weight of UTIL) then the payback adjusted for UTIL non-zero is:

$$\text{Adjust Payback} = APB = \frac{W_{PB}}{\frac{W_{PB}}{PB} + (1-W_{PB})^{*}\ UTIL}$$

Note: when UTIL = 0.0, APB = PB.

The penetration curve is used with the adjusted payback APB in place of the unadjusted payback PB.

The penetration logic must also account for the selection of a multiplicity of device types (e.g., hot water only; hot water and space heating; and hot water, space heating and air conditioning). This is performed using a sequential approach to penetration wherein the lowest first-cost device is considered and the other more costly devices are penetrated on the basis of the marginal payback associated with stepping up from a hot water only device to more comprehensive devices. The approach tends to place an emphasis on first costs and also tends to spread the market out evenly when the solar devices are equally competitive. The multiple-device approach also tends to concentrate the penetration of devices which are clearly superior to the others.

III. EXPERIENCE EFFECTS

Experience affects the way in which both the supply and demand markets respond to incentives and device economics. Generally, experience is measured as the total national square feet of solar device installation on both an annual production and a cumulative production basis. A minor component of experience, however, is considered specialized to specific market building type and regional area. The national experience is developed as a ratio to initial (1976) experience.

$$EXP_N = \text{NATIONAL EXPERIENCE} = \alpha \frac{A}{A_O} + (1 - \alpha) \frac{C}{C_O}$$

Where A = level of annual solar device sq ft installed - nationally

A_O = level of initial annual solar device sq ft installed - nationally (e.g., 1976)

C = level of cumulative solar device sq ft installed - nationally

C_O = level of initial annual solar device sq ft installed - nationally (e.g., 1976)

α = annual/cumulative experience weighting factor.

The special region and market experience is just the ratio of initial to present market penetration.

$$\text{Market/Region Specific Experience} = EXP_{M/R} = \frac{PENE}{PENE_O}$$

Where PENE = last year's market penetration

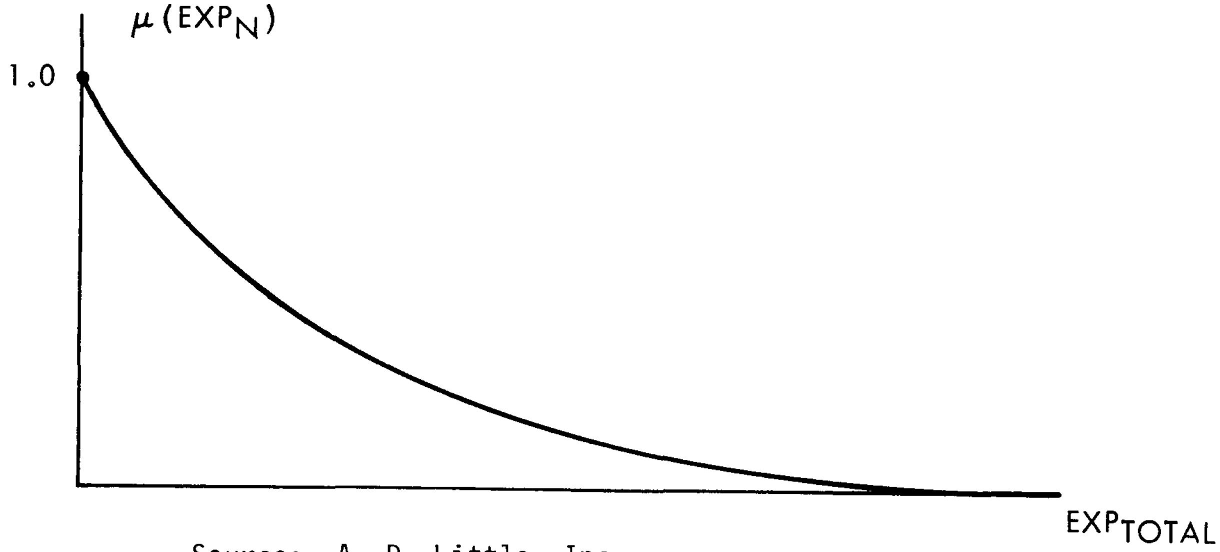
$PENE_O$ = initial year's market penetration (e.g., 1976)

The experience - both national and specific - are used to calculate per square foot solar device costs and the degree to which the "initial" or "final" market penetration curves are to be used.

$$EXP_{TOTAL} = \gamma\ EXP_N + (1 - \gamma)\ EXP_{M/R}$$

is the total experience. The weighting of the initial curve tends to decrease as a functional of EXP_{TOTAL} as shown in Figure D-4.

Where, γ = weighting factor.



Source: A. D. Little, Inc.

Figure D-4 - Relationship Between Total Solar Energy Experience and Market Penetration

The penetration curve for any level of experience EXP_N is thus:

$$PENE\ (EXP_N;PB) = \mu(EXP_N) * PENE_{INITIAL}\ (PB) + (1-\mu) * PENE_{FINAL}\ (PB)$$

Thus, penetration is a function of both payback and experience.

The cost per square foot of solar collector system installed is also a function of experience. The per square-foot function is

$$C_{SF} = COST/SQ\ FT = C_A + C_B\ (SF)^{C_N}$$

where C_{SF} = cost (\$) per square foot

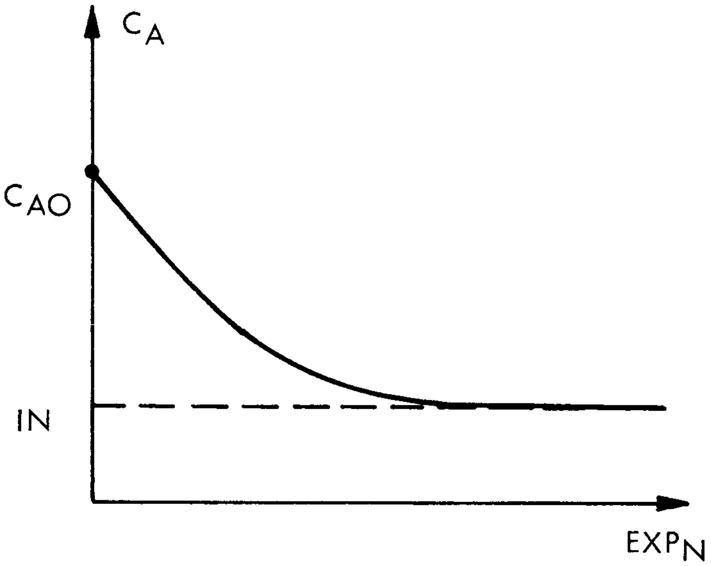
C_A = production cost component

C_B = installation cost component

C_N = installation cost exponent

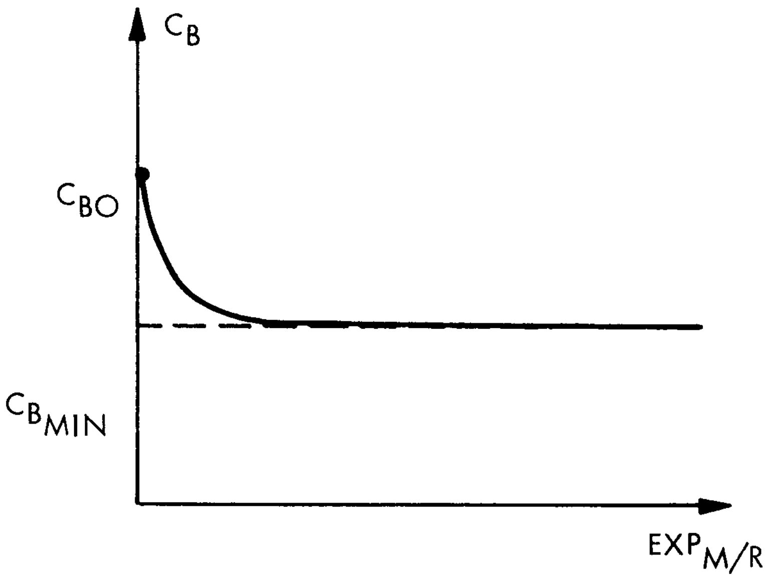
SF = size of unit in square feet.

The values of C_A and C_B are postulated to drop to a minimum lower-bound, constant-dollar cost level as a function of national and market/region experience, respectively. Figures D-5 and D-6 indicate the forms of the relationship.



Source: A. D. Little, Inc.

Figure D-5 - Relationship between Production Cost Component and National Experience



Source: A. D. Little, Inc.

Figure D-6 - Relationship between Installation Cost Component and Market/Region Experience

IV. LIMITATIONS

The methodology which is being used in this model is similar to that used by ADL in numerous public and private assignments in the area of solar energy and other analyses of conventional energy conservation. While it is felt that this methodology accurately simulates consumer response to the economics of decisions in the energy area of the construction industry, it should be noted that, as in any simulation, it has limitations.

First, for reasons of workability, the model must deal with consumer characterization and response in aggregate. Thus, "decision modules" have been defined for each of 14 years (1977-1990) to represent the tens of millions of actual decision makers (owners and users of buildings) who will eventually determine the success or failure of solar energy. It is recognized that each of these decision makers is unique, and has unique characteristics which will impact their decision on whether or not to use solar energy systems.

Likewise, the characteristics of the buildings considered by each of these decision makers is different, with different energy consumption characteristics, different marginal fuel rates, different designs, and different usage patterns. Within each of the decision modules there will obviously be a distribution of characteristics on both sides of the mean which have been used in the model. From these different characteristics will come a concomitant distribution of the economic performance of solar energy systems. Even in modules where it is predicted "no penetration" for certain solar systems, there are likely to exist building units with the necessary combination of unit characteristics, owner characteristics, and conventional fuel situations to make the decision to use solar energy a rational one.

In aggregate, however, it is felt that the estimates which result from the use of a model, such as has been developed, will approximate the workings of the "real" world. Major differences which may occur between prediction and reality will result primarily from changes in external conditions (such as fuels prices, systems costs, public and private policies) from those which we have predicted (or assumed), and incorporated into the model.

Such changes might well occur in each of the three areas listed above. In the model, fuel price data supplied by FEA have been used, which essentially represent modest inflation of fuels prices over the next decade relative to the general economic inflation. If prices should in fact rise at a rate even closely approximating that experienced since the Arab oil embargo of 1973, the economics of solar energy (and concurrently the predicted response of consumers to solar energy systems) will improve dramatically. Because usage of solar energy increases sharply with higher fuel prices (the slope of the penetration curves increases rapidly up to a 50% penetration), this average price assumption will tend to understate solar energy usage. In addition, the FEA prices assume single prices for each FEA region, when in reality each region has a broad range of prices (especially for gas and electricity) above and below this average.

Similar results will occur if breakthroughs in the technology or cost of solar equipment exceed those which have been built in the simulation. Extensive private and public support of the concept of solar energy could shift anticipated consumer response patterns significantly, and thus further promote the development of a solar industry.

V. APPLICATION

In fact, one of the major purposes of this model is to test the effect of potential changes in external conditions to the development of solar energy as an alternative fuel source. While much of the effort went into modeling conditions which are felt to be a reasonable approximation of what should happen in the environment over the next 14 years, significant additional effort has been placed in modeling and analyzing potential changes in these conditions. The uncertainties of economic forecasting are well documented. When such forecasting is applied to technologies which are emergent, the margin for error increases dramatically. An effort has been made in this project to use baseline projections as benchmarks for the testing of alternative scenarios in the areas of government policy, systems economics, and consumer attitudes. By analyzing the effects on the development of solar energy of a series of "what if" statements, it is hoped to identify those areas which seem most beneficial to pursue, both in terms of development of policy, and further study and analysis.

It is recognized that different methodologies have been used, and are being used, by other parties to project not only solar energy usage, but also other advanced forms of energy technology. Readers are cautioned in the making of comparisons between the results contained in this report and those developed by other sources using different methodologies. Only by applying a similar methodology to the assumptions underlying other such estimates can meaningful comparisons be made.

VI. INPUT ASSUMPTIONS

The specific input assumptions of the FEA/ADL model are not yet available at the time of this report. Such documentation will be contained in a subsequent FEA report concerning the model. In this section, the types of inputs to be used will be discussed with examples of the format presented.

The first section deals with building inventory and loads, followed by fuel share and price inputs. The section is concluded with a short discussion of solar energy system characteristics and costs.

A. Building Inventory and Energy Demand

The FEA/ADL Solar Incentive Model is applicable to the residential, commercial, and institutional building markets in the United States. Industrial and agricultural applications are not considered. The market is also divided into the 10 FEA regions (Figure D-7) for the time period of 1977 to 1990. The building/market types are summarized in Table D-1. Note that the non-residential sector is divided into two building types: (1) those that use large amounts of hot water, such as a laundry or restaurant, and (2) those that do not use a large amount of hot water. It should be further noted that several building types are subdivided into separate markets, e.g., multi-family dwellings are subdivided into condominiums and rental units. There are a total of 10 building/market types.

The building inventory is derived by taking the pre-1977 inventory (Table D-2) and adding the projected new construction (Table D-3) and subtracting the expected building retirements (Table D-4). Although these tables show national averages, the model will eventually project building inventory within each of the 10 FEA regions. The pre-1977 inventory is considered to be the retrofit market, which is handled separately from new construction.

Theoretical building loads are developed for each region and building/market type by end use (e.g., water heating, air conditioning, etc.). Table D-5 shows an example of building loads for a single family residence in the New England region. Degree day data was taken from the Climatic Atlas and is shown in Figure D-8.

B. Fuel Shares and Prices

Four competitive energy sources are considered. Natural gas and oil distillate are used as fuel for hot water and space heating. Electricity is consumed for hot water, space heating and cooling applications. Heat pumps are used for space heating and cooling applications only. The fuel firing efficiencies are as follows:

Gas	0.7
Oil	0.6
Electricity	0.1
Electric Heat Pump:	
Heating	1.5
Cooling	2.1

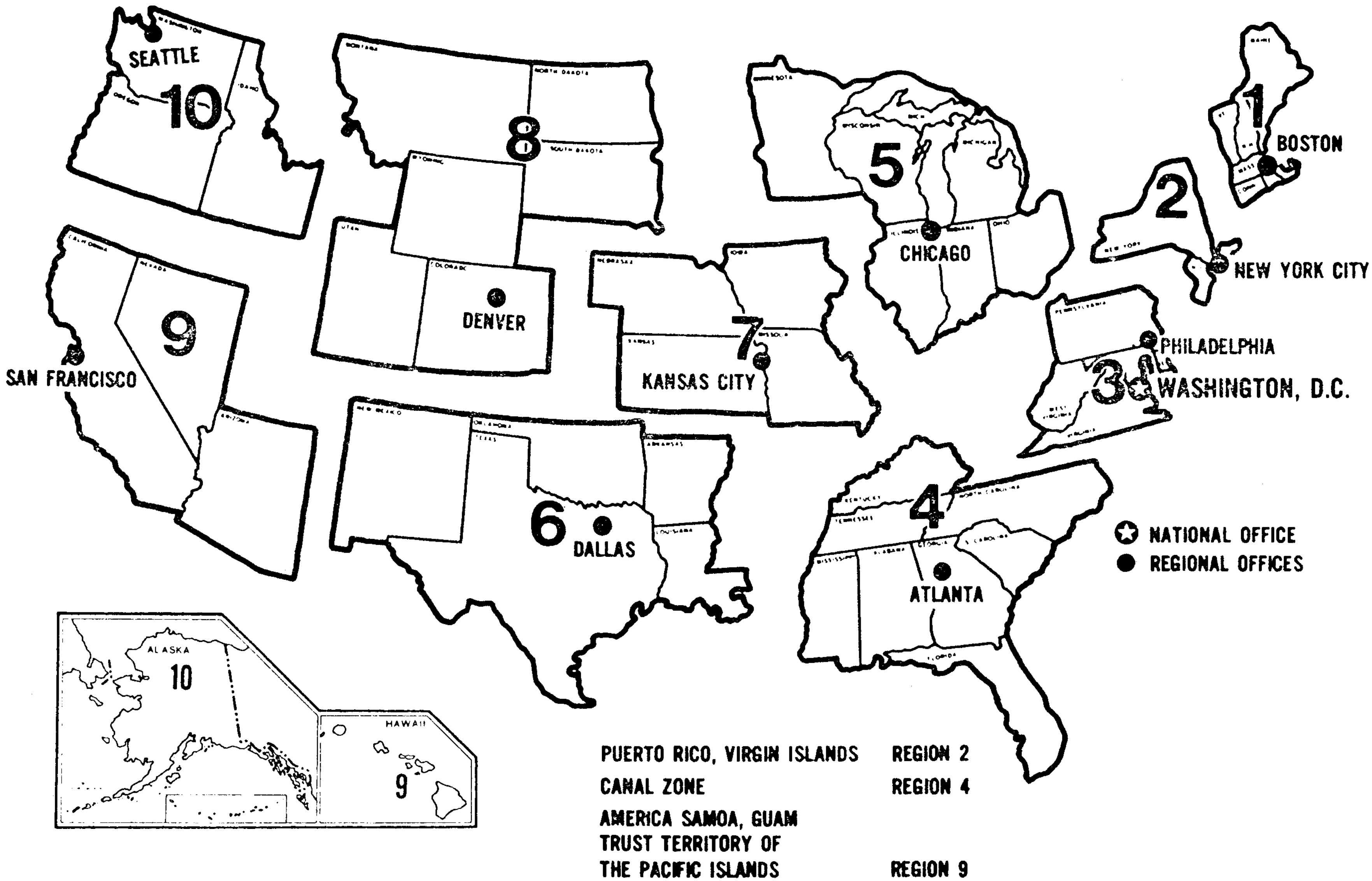


Figure D-7 - Federal Energy Administration - Regions

TABLE D-1

BUILDING/MARKET TYPES

	Building Type (6)	Market Type (10)
Residential	Single Family	Single Family
	Low Density Units (2-3 family attached)	Low Density
	Multi-Family Units (over 3 families)	Condominiums Rental Units
	Mobile Homes	Mobile Homes
Non-Residential (commercial and institutional)	High Hot Water (hospitals, restaurants, laundries)	Institutional Owner/Lessor
	Low Hot Water (all other non-non-residential)	Institutional Owner/Lessor Owner Occupied

TABLE D-2

Pre-1977
BUILDING INVENTORY

	Residential (000 Units)	Non-Residential (MM Sq Ft)
Single Family	49,175	
Low Density	10,984	
Multi-Family	12,538	
Mobile Home	3,847	
High Hot Water		3,501
Low Hot Water		20,962

TABLE D-3

1977-1990
ANNUAL BUILDING PROJECTIONS

	1977	1980	1985	1990
Residential (000 Units)				
Single Family	1,207	1,055	1,130	1,170
Low Density	201	205	250	320
Multi-Family	392	400	430	470
Mobile Home	300	325	370	400
Non-Residential (MM Sq Ft)				
High Hot Water	147	157	160	165
Low Hot Water	680	677	675	690

TABLE D-4

BUILDING RETIREMENTS

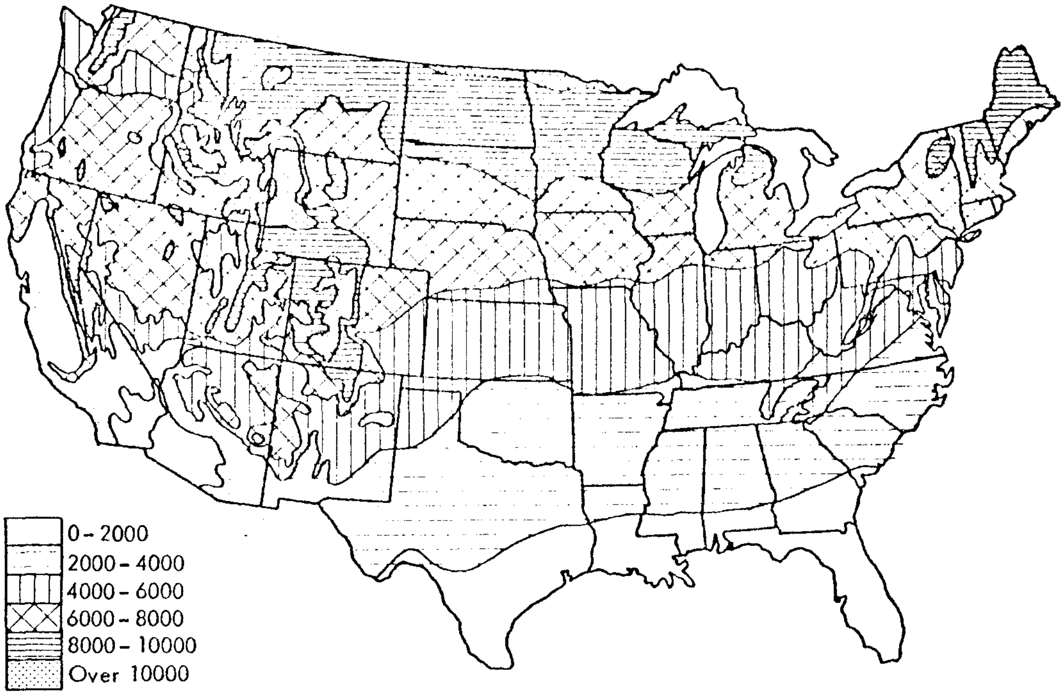
	Average Annual Units/Year
Residential	(thousand units)
Single Family	180
Low Density	40
Multi-Family	45
Mobile Home	45
Non-Residential	(million square feet)
High Hot Water Low Hot Water	170

TABLE D-5

THEORETICAL BUILDING LOADS

Single Family - Region I (New England)
(MM BTU/Unit)

	Pre-1977 Inventory			New Consutrction 1977			New Consutrction 1990		
	Gas	Oil	Elec.	Gas	Oil	Elec.	Gas	Oil	Elec.
Water Heating	22	22	22	19	19	19	15	15	15
Space Heating	130	126	71	112	112	89	81	81	68
Air Conditioning	--	--	5	--	--	7	--	--	7
% Air Conditioning	--	--	27%	--	--	47%	--	--	47%



Source: Climate Atlas of U.S., Environmental Data Service, U.S. Department of Commerce, June 1968.

Figure D-8 - Regional Distribution of Annual Degree Days of Heating

Regional fuel shares by end use are being developed by FEA for the model and were not available at the time of the report. Fuel price projections were taken from FEA's Project Independence Evaluation System (PIES) and are summarized in Table D-6.

C. Solar Energy Systems

Three applications of solar energy are considered in the model: (1) hot water, (2) hot water and space heating, and (3) hot water, space heating and cooling. The model assumes no one would choose space heating system, for example, without hot water capabilities. Collector costs are expressed as total system first costs expressed in $/ft^2 of collector area. System efficiencies are also estimated for each device. These estimates are re-evaluated each year. Table D-7 shows costs and efficiencies for a representative hot water system in 1977 and 1990.

Systems are sized to meet a certain percent of the total building load. Sizing is a function of region and system type. Insolation data are taken from the Climatic Atlas and portrayed graphically in Figure D-9.

TABLE D-6

ENERGY PRICE ASSUMPTIONS OF FEA/ADL MODEL OF SHACOB PENETRATION

Part A; Residential Energy Prices
(In 1977 Dollars Per Million BTUS)

Year and Fuel Type	1 New England	2 New York/ New Jersey	3 Mid-Atlantic	4 South Atlantic	5 Midwest	6 Southwest	7 Central	8 North Central	9 Western	10 North Western	National Average
	FEA Region*										
1975											
Electricity	14.53	16.32	12.24	9.01	10.66	8.70	9.79	9.02	10.83	4.66	10.34
Natural Gas	3.37	2.75	2.12	1.64	1.68	1.48	1.42	1.29	1.68	2.30	1.81
Fuel Oil	3.44	3.13	3.06	3.08	2.90	2.99	2.94	3.08	3.29	3.22	3.11
1980											
Electricity	14.43	15.60	11.94	10.40	11.05	13.70	11.27	9.25	13.92	6.64	11.72
Natural Gas	3.39	3.13	2.69	2.24	2.21	1.80	1.69	1.70	2.42	3.35	2.32
Fuel Oil	3.54	3.59	3.76	3.83	3.30	3.53	3.20	3.40	3.48	3.48	3.53
1985											
Electricity	14.25	14.86	12.37	10.51	11.48	12.89	11.18	8.97	13.11	6.51	11.65
Natural Gas	4.14	3.63	3.24	2.86	2.74	2.04	1.72	1.77	3.59	3.36	2.80
Fuel Oil	3.69	3.77	3.94	4.02	3.58	3.71	3.49	3.68	3.70	3.70	3.74

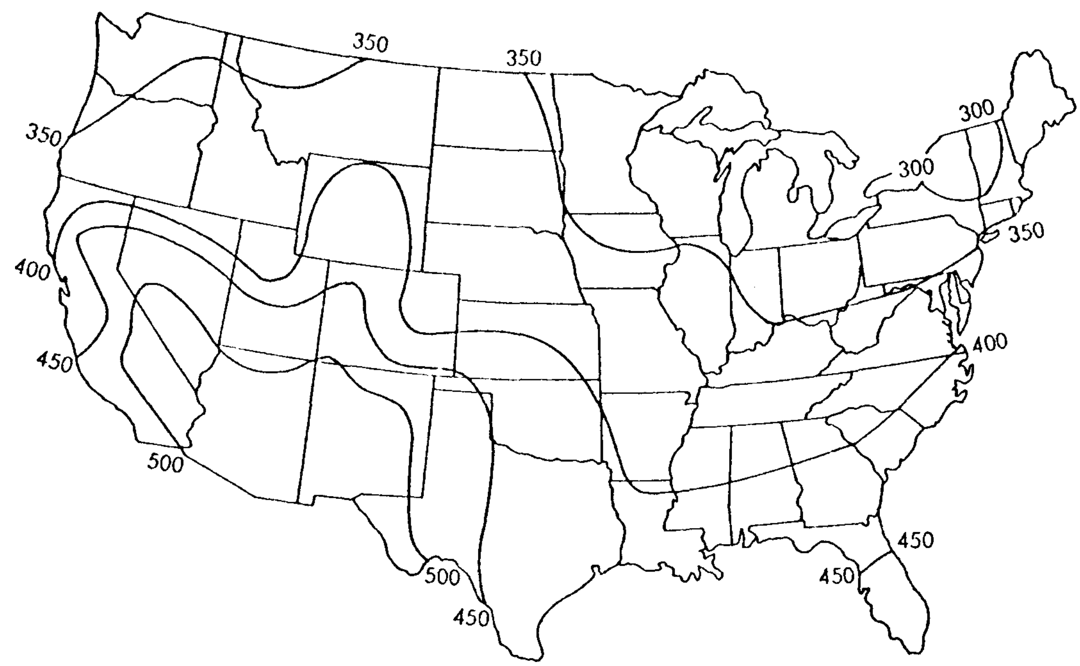
Part B; Commercial Energy Prices
(In 1977 Dollars Per Million BTUS)

Year and Fuel Type	1 New England	2 New York/ New Jersey	3 Mid-Atlantic	4 South Atlantic	5 Midwest	6 Southwest	7 Central	8 North Central	9 Western	10 North Western	National Average
	FEA Region*										
1975											
Electricity	14.15	16.41	11.38	9.44	10.43	7.60	9.09	7.58	9.12	4.88	10.17
Natural Gas	2.79	2.23	1.81	1.30	1.42	1.00	1.07	1.08	1.37	1.73	1.44
Fuel Oil	3.05	2.85	2.84	2.84	2.74	2.74	2.75	2.95	3.01	2.95	2.86
1980											
Electricity	14.19	16.48	11.24	10.68	10.92	12.87	10.42	8.13	12.62	6.74	11.79
Natural Gas	2.76	2.56	2.25	1.76	1.90	1.30	1.30	1.48	1.93	2.80	1.87
Fuel Oil	3.31	3.35	3.39	3.40	3.12	3.28	3.04	3.18	3.22	3.22	3.27
1985											
Electricity	14.16	16.53	11.83	10.63	11.46	12.32	10.93	8.17	12.23	6.49	11.78
Natural Gas	3.51	3.07	2.80	2.38	2.43	1.99	2.30	2.40	3.10	2.81	2.60
Fuel Oil	3.47	3.53	3.57	3.58	3.41	3.47	3.32	3.47	3.44	3.44	3.48

* The FEA regions are defined in Appendix D.

TABLE D-7

	Representative Hot Water System	
	1977	1990
System Costs (per sq ft)	$40.00	$25.00 (1977 dollars)
System Efficiency	35%	40%



Source: Climatic Atlas of U.S., Environmental Data Service, U.S. Department of Commerce, June 1968.

Figure D-9 - Mean Daily Solar Radiation Distribution (Langleys on a Horizontal Surface)

APPENDIX E

COMPARISON WITH OTHER ENERGY INVESTMENTS

APPENDIX E

COMPARISON WITH OTHER ENERGY INVESTMENTS

TABLE OF CONTENTS

The comparative economic analysis of federal investments in alternative energy sources is dependent on more than the values incorporated in private sector market evaluations. Presently, SHACOB's market value as perceived by potential investors, may be significantly less than its value to the nation as a whole. Economic and social costs associated with conventional energy sources, such as pollution, negative influences on national security, and the depletion of nonrenewable energy sources must be considered when comparing government investment in SHACOB to conventional energy sources. The costs of previous governmental actions to subsidize other energy industries must also be considered.

This appendix is divided into two major sections. Section I discusses a conceptual justification for a social cost-benefit analysis from which federal investments in alternative energy sources can be compared. Section II documents in detail previous federal investments (subsidy programs) provided to conventional energy industries.

I. COMPARATIVE EVALUATIVE FRAMEWORK: FEDERAL ENERGY INVESTMENTS

A. Introduction

Historically, government energy investment (subsidy) programs have been based on the broadest interests of society. Research, Development and Demonstration (RD&D) expenditures and various other subsidies have been and are considered national investments in the future. For SHACOB related technologies, government investments are made in future renewable energy sources that form part of the long-term solution to the nation's energy problems. The return on such national investments may not begin until 10 to 25 years from their inception, as evidenced by the government nuclear energy program. The federal government, however, takes a larger time frame into account than individuals or corporations. The government is probably the only organization that would be willing to invest in a venture with so many years before payoff. The exact time frame appropriate for government energy investments, however, is under considerable debate among economists, political scientists and others.

B. Cost-Benefit Analysis of Government Energy Investments - the Justification

The debate over appropriate time frames for government energy investments is best reflected in the controversy over social discount rates utilized in cost-benefit analyses. For evaluative purposes, the discount rate is applied to future costs and benefits of investments in government energy programs to account for the investment opportunities which are foregone by spending funds in the present. The discount rate should reflect the value of time to the decision-maker. Therefore, the social discount rate should reflect the value that society places on time.

A wide variety of social discount rates are used by economists. These rates vary from zero to almost 15%.1/ A social discount rate of zero implies that the future is valued as much as the present, and that there is a one to one trade-off between present and future costs.* Zero is an unconventional value for the discount rate because it implies that time has no value. In other words, receiving a sum of money 10 years from today is exactly equivalent to receiving the same sum today. No account is taken for investment opportunities that are given up today by not receiving the sum until the future.

Although the time horizon for government investments is questionable, there is some agreement among economists that the expenditures should yield a positive return in the future. The return on government energy investments does not necessarily have to be monetary, nor does it have to be received directly by the government. The return may be non-monetary in nature and could be received by any group or groups within the society.**

If the investment yields a positive social return, using some prespecified social rate of discount, the nation will be better off than before the program. The phrase "better off" is a value judgement that requires further clarification. The value judgement assumed for cost-benefit analyses is that more goods and services are preferred to less.

The cost-benefit approach is used for comparative analyses. It assumes that the satisfaction lost by an individual who bears $1.00 of the cost of a project is equal to the satisfaction gained by the individual receiving a dollar in benefit. In other words, it assumes that the marginal utility of all individuals in the society is constant. This assumption can lead to many types of misconceptions about the trade-off between social costs and benefits. Impacts on the distribution of income will be especially misrepresented. Although this drawback of cost-benefit analysis is realized, no acceptable way of avoiding it has been formulated.

In summary, government energy investments for research, development and demonstration expenditures, and even permanent subsidies can be regarded as societal investments. These investments should yield some societal benefit in the future. The benefit must be at least large enough to recoup the

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1/ A variety of discount rates used by economists is summarized in "Our R&D Economics and the Space Shuttle," by Klaus Heiss (Astronautics and Aeronautics), October 1971, p. 57.

* Some individuals hold that resources for future generations should be valued higher than the present generation. This argument would support the use of a negative social discount rate.

** Those sectors receiving these social benefits may not be the same sectors that paid for the investment.

initial investment, cover the cost of time between the outlay and the payoff (expressed by the social rate of discount), and pay society for the risks of the investment. Any benefit above this minimum will make the society better off than before the investment. Governmental investments for solar RD&D programs and other energy technologies should be compared from the national or societal investment viewpoint.

C. Cost-Benefit Analysis of Government Energy Investments - the Strategy

A national investment in solar energy research, development and demonstration must be compared to similar investments in other energy technologies based on the following factors:

- Social (i.e., national) value of not polluting the environment as a by-product of energy production.
- Social value of not depleting finite energy resources in the production of energy.
- Social value of insurance against foreign energy curtailments, restrictions, or price increases.
- Social value of solar technology for exportation to other nations.
- Social value of information gained that could be transferred to other energy problems (e.g., the development of practical energy storage systems).
- Any improvement in national employment or economic conditions due to the RD&D program or the growth of a new industry.
- Any subsidies on displaced conventional energy sources.

The investment decision to spend government funds on any aspect of solar energy development versus other energy technologies should be based on the social benefits derived from each. The magnitude of governmental energy investments should also be limited by the size of their social benefits. The difference between the social benefits of solar technologies (over some long period of time) and the social costs of production should equal the maximum amount the government should subsidize (or invest in) an energy technology.

This approach to determining justifiable government investments requires that a social cost-benefit approach be used. The social costs to be considered include:

1. The private market price (i.e., the private-sector costs of production);

2. Existing or proposed government subsidies; and

3. Any other external social costs (external to the private sector price mechanism).

The first element of the social cost attributable to an energy technology should reflect the private sector valuation of the materials, labor and capital expended toward its production. Technological advances in production techniques and economies of scale due to expanded demand should alter this cost element over time.

The second cost element is government subsidies to an energy technology. The purpose of Section II of this appendix is to estimate the magnitude of these subsidies. Thus, the magnitude of the subsidy is a dependent variable in the analysis.

Any other external social costs are included in the third element of the social cost. These external costs include any environmental damage, negative impacts on national security, or significant health and safety hazards.

The social benefits of an energy technology can also be divided into three parts including:

1. The value of the energy produced to the private sector;

2. Any subsidies on existing energy sources that are displaced; and

3. Any other social benefits.

The first social benefit represents the private market value of energy that a private sector decision-maker would be willing to pay. The current tax structure and subsidies to competing energy technologies affect this decision, and are therefore included. Within the private sector environment, SHACOB's value critically depends on the market price of competing energy sources.

The second social benefit that would accompany the development of solar technologies is the reduced subsidies on displaced conventionally produced energy. Currently, subsidies on conventional energy systems reduce the percentages of social cost that enter the private sector decision process. This market distortion due to subsidies should be eliminated from a social cost-benefit analysis.

The final element of a social benefit analysis should include those benefits external to the private sector and not currently affected by governmental subsidies. These benefits include the value of pollution abatement, health and safety, conservation of energy resources, insurance against foreign energy curtailments, exports, transferable knowledge, and improvements in economic conditions.

Finally, before any cost-benefit estimates can be made, two critical areas must be addressed. First, an appropriate time frame must be chosen. Second, the benefits and costs must be expressed in common units. Also of critical importance is the clear understanding of the role previous governmental investment (subsidy) programs have played in the development of other energy technologies. Section II of this appendix provides a detailed investigation into the history of government subsidies to conventional energy sources. It analyzes the purpose, impact and extent of many previous energy subsidy programs.

II. DISCUSSION OF ENERGY INDUSTRY SUBSIDIES

Section II* of this appendix contains four parts. The introduction, Section A, provides an overview of energy subsidies. Section B describes the impact that several special tax provisions have had on industry segments (especially petroleum). Section C provides examples of how governmental policies designed in the name of "national security" have subsidized segments of the energy industry by increasing the energy prices consumers pay and by reducing competition. Several direct federal subsidy programs provided to demonstrate the economic and technical feasibility of nuclear energy industry are discussed in Section D.

A. Introduction

The term subsidy frequently refers to a government program or policy designed to aid a particular industry, organization, or type of enterprise. Normally, subsidies have been justified for many U.S. industries as a necessary expenditure or cost required for vital national interests or defense. The tariff system acts as a subsidy structure, since it enables the protection of certain industries and results in higher costs for their goods in the American market. Depletion allowances have provided subsidy-like benefits to several industries (especially petroleum), as have accelerated tax amortization write-offs, provision of free or less than full cost government services, and many others.

Generally a subsidy, at least conceptually, involves a governmental action designed to improve the economic position of an industry or individual. The aim is to enhance profitability which would be less without the protection

* This section is based on work done by Midwest Research Institute in Conceptual Design and Systems Analysis of Photovoltaic Power Systems, Subcontract to Spectrolab, Inc., for ERDA, ERDA Contract E(11-1)-2748, January 1977.

of these various statutes. While designed to soften the full force of competition, the implicit objective of each governmental action has been to encourage further development and commercialization of one or more segments of the energy industry. Generally, each action was taken in response to a specific problem which was believed to be a barrier restricting commercial development. Historically, some segments of the energy industry have enjoyed many special governmental provisions which have directly or indirectly subsidized their operations.

Since the early 1900's, a series of legislative actions have evolved a maze of overlapping and fragmented regulations and subsidies. The provisions of each action have not equally applied to each industry segment. The results of each provision have not had the same impacts on each segment. While a number of special provisions that benefit the industry can be located, analysis of their impact cannot. Only a few studies have attempted to assess the impact of the existing legislative maze. And these studies have been narrow in scope, limiting themselves to the evaluation of specific provisions of specific industry segments, rather than attempting a comprehensive industry analysis.

Table E-I highlights the influence a few governmental subsidy programs have had on different energy industry segments. The following sections of this appendix discuss the origin, rationale, and impact of these special governmental provisions in detail. The objective is not to provide a comprehensive analysis of all the subsidies provided the energy industry, but rather to illustrate the significant influence certain governmental actions have had on a few energy industry segments.

Briefly, paragraph B of Table E-I first highlights several distinctive tax provisions certain energy industry segments (the oil and gas industries) benefit from. Apart from certain types of capital gain transactions, the important special provisions applicable to specific industry segments are of three types:

1. The most important, and controversial, special tax provision was and is the "percentage depletion allowance." Under this provision, a percentage* of the gross value of oil produced (up to a limit of 50% of net income) should be deducted before computing income for income tax purposes. In origin, this was to serve as a substitute for an earlier method of allowing an annual depletion charge against the capital value of oil discovered, in lieu of depletion based on costs incurred. Some studies indicate the impact of this tax provision may have reduced the oil producers costs by 10% or more.

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* The percentage depletion allowance is currently being discounted for major oil and gas companies, but was 22% from 1970 through 1975; 27.5% from 1926 through 1969; and varying amounts before 1926.

TABLE E-I

TYPICAL SUBSIDIES UTILIZED BY MEMBERS OF THE ENERGY INDUSTRY

	Annual Subsidy ($ millions)	Energy Costs: With Subsidy ($ millions)	With Subsidy Per Unit	Without Subsidy ($ millions)	Without Subsidy Per Unit	% Impact on Costs
B. Special Tax Provisions (Decreases Costs) (Oil and Gas Industry)			/barrel[5/]		/barrel	
(1) Percentage Depletion CONSAD Study (1965 Base)	1,200[1/]	12,018	$2.86	13,218	$3.14	10.0%
(2) Intangible Drilling Exp. CONSAD Study (1965 Base)	$119-$324[1/]	12,018	2.86	12,137-12,342	$2.89-2.94	1.0-2.7%
Both (1) and (2) CONSAD Study (1965 Base)	1,400	12,018	2.86	13,419	3.19	11.6%
Span et al. Study (1971 Base)	2,500[2/]	18,724	3.39	21,224	3.84	13.4%
(3) Foreign Tax Credit Ways and Means Study (1971 Base)	500-600[4/]	18,724	3.39	19,224-19,324	3.48-3.50	2.7-3.2%
C. Import Controls (Increases Prices) Domestic Petroleum Industry			/barrel[5/]		/barrel	
(1) Presidential Petroleum Study (1967 Base)	3,500[6/]	13,433	2.93	9,933	2.16	26.1%
(2) Cicchette and Gillen (1970 Base)	7,400[7/]	17,059	3.18	9,659	1.80	43.4%
D. Federal Subsidy Programs (Decreases Costs)			mils/kw-hr		mils/kw-hr	
(1) Econ. of Nuclear Power (1975 Base)	($ billions) $24.4	($ billions) 6.1	12.5[8/]	($ billions) 30.5	62.9	403%

TABLE E-I (Concluded)

Discussion

B. Special Tax Provisions: The figures in Table E-I refelct the size of some tax subsidies provided to the domestic petroleum industry. The base year in which the annual subsidy was estimated is indicated. The percentage impact on cost only serves as an example of the influence these tax provisions had on petroleum costs at that point in time. No attempt has been made to expand the time frame to calculate the cumulative effect of these special tax provisions or measure their impact on other members of the energy industry. All subsidies are calculated in terms of tax revenue lost by the U.S. Treasury.

1/ CONSAD Research Corporation, The Economic Factors Affecting the Level of Domestic Petroleum Reserves, Pt. 4, U.S. Congress Committee on Ways and Means and Senate Committee on Finance, Tax Reform Studies and Proposals, U.S. Treasury Department, Government Printing Office, Washington (1969).

2/ Spann, Robert M., Edward W. Erickson, and Stephen W. Millsaps, Percentage Depletion and the Price and Output of Domestic Crude Oil, Panel discussion on general tax reform, Panel No. 9--Natural Resources, U.S. Congress, House Committee on Ways and Means, 93rd Congress, 1st session, Government Printing Office, Washington (1973).

3/ U.S. Congress, Senate Committee on Interior and Insular Affairs, Financial Requirements of the Nation's Energy Industry, Serial No. 93-5, March 6, 1973.

4/ Staff of the Joint Committee on Internal Revenue Taxation, Energy Taxation: Possible Modifications in the Tax Treatment of Foreign Oil and Gas Income, Study No. 3, prepared for use by the Committee on Ways and Means, U.S. Congress, 94th Congress, Government Printing Office, Washington (1974).

5/ Bureau of Mines, Mineral Industry Surveys, "Petroleum Statements" Annual.

C. Import Controls: These figures reflect the added costs borne by the U.S. public in terms of costs payed over the competitive world prices.

6/ Executive Office of the President, Office of Emergency Planning, A Report to the President, by the Petroleum Study Committee (September 4, 1967), p. 2. Resources for the Future, U.S. Energy Politics: An Agenda for Research (1968).

7/ Charles J. Cicchetti and William Gillen, "The Mandatory Oil Import Quota Program: A Consideration of Economic Efficiency and Equity," in the Economics of Federal Subsidy Programs, U.S. Congress, Joint Economic Committee, Washington, U.S. Government Printing Office, p. 1013.

8/ ERDA, The Economics of Nuclear Power, ERDA, Office of Public Affairs (EDM-068 (-76)), March 1976.

2. Intangible drilling expenses, which represent the major fraction of capital costs of wells, are permitted to be charged as current expenses instead of being written off over the life of the wells. This has the same advantage, in an extreme form, of any system of accelerated depreciation. It decreases current income taxes during a period of development and gives command over a volume of cash funds that may be thought of as an interest-free loan. The effect of this provision on crude oil costs has been estimated to be from 1 to 14%.*

3. Foreign tax credits used by the oil and gas industry on treatment of income earned abroad have also acted as a subsidy. Their impact has been estimated at approximately 3%.

Secondly, the subsidies provided to several industry segments in the form of import controls used to guarantee national security are shown in paragraph C of Table I. The rationale for the use of import controls, including quotas and tariffs, is to assure the United States economy of a stable energy supply. The impact of these controls has been to reduce competition and artificially increase energy prices paid by the consumer. Studies assessing the subsidy and social costs of import control programs vary, but indicate it to be substantial. For example:

1. The magnitude of the subsidies provided to domestic oil companies by consumers through artificially increased prices range from 25 1/ to 45%. 2/

2. Additional social costs borne by the public measured in terms of economic inefficiencies attributable to import quotas were estimated to equal $3.5 billion in 1970. 2a/

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* Estimates of the combined impact of these two special provisions have ranged from 12 to 24%. Since actual capital outlays are recoverable through current expensing of intangible costs and depreciation of tangible assets, the depletion allowance is in effect an extra benefit. Moreover, it goes on without limit of time or amount, as long as there was a net income.

1/ Executive Office of the President, Office of Emergency Planning, A Report to the President, by the Petroleum Study Committee, September 4, 1962, p. 2; Resources for the Future: U.S. Energy Policies, an Agenda for Research, 1968.

2/ Cicchetti, Charles J., and William Gillen, "The Mandatory Oil Import Quota Program: A Consideration of Economic Efficiency and Equity," in The Economics of Federal Subsidy Programs, U.S. Congress, Joint Economic Committee, Washington, U.S. Government Printing Office, p. 1013.

2a/ Ibid.

The final program area of subsidies covered by this appendix concerns government participation and support of energy industry projects and R&D. These programs have acted to reduce the financial and institutional barriers restricting the development and commercialization of several industry segments. The case history concerning the growth of the nuclear power industry provided in Section D of this appendix illustrated the immense impact of government subsidies. Without these special governmental actions involving R&D programs, incentives to discover uranium and funding of nuclear power stations, the nuclear industry would have never developed to its present stage of commercialization.

1. A full cost analysis of 1976 subsidies provided the nuclear energy industry amounts to 50.5 mills/kw-hr. This consists of 21.8 mills/kw-hr indirect costs and 28.7 mills/kw-hr in R&D programs. The magnitude of this subsidy equals four times the normally quoted busbar costs for nuclear energy.

2. The total amount of subsidies provided to the nuclear industry since 1956 has amounted to $26.4 billion. This is equivalent to $40.5 billion in constant 1975 dollars.

B. Special Tax Provisions

1. Description: Historically, segments of the energy industry (especially petroleum) have received special treatment under federal tax laws and regulations. The depletion allowance, expensing of intangible drilling costs, and the U.S. tax credit for payment to foreign governments for production rights have acted as subsidies. The result of such special tax treatment has been a loss of revenue to the U.S. Treasury. The descriptions of the distinct tax provisions for the petroleum and gas industries do not equally apply to other mineral extractive industries.

a. Depletion allowance: Most firms engaged in oil, gas and other mineral extraction are permitted to include in their business costs a "depletion" allowance for the exhaustion of the mineral deposits. Depletion is similar in concept to depreciation. The depletion allowance is used to recover the cost of a mineral deposit. There are two methods of calculating depletion: percentage depletion and cost depletion. Those who qualify for the percentage depletion must use it when the percentage depletion is greater than the cost depletion.

Under percentage depletion, a taxpayer (individual or corporation) deducts from taxable income a fixed percentage of gross income resulting from mineral extraction as a depletion allowance regardless of the amount invested in the deposit. The deduction for gas and oil (which was 27.5% from 1926-1969) was set at 22% of gross income until 1975. In that year, the percentage depletion allowance was repealed for major oil and gas companies. Other companies (independents) have been exempted from repeal of 2,000 barrels a day for 1975. The amount of this exempt portion is being phased down gradually to 1,000 barrels a day. In addition, beginning in 1981, the depletion rate will be gradually phased down to 15% for qualifying producers.

Percentage depletion also applies to other mineral resources at percentages currently ranging from 22 to 5%. Sulphur, uranium, and most other metal minerals in the U.S. qualify for the 22% rate; however, domestic gold and iron ore qualify for a 15% rate; most minerals mined outside the U.S. qualify for a 14% rate; coal qualifies for a 10% rate; and several forms of clay, gravel and stone qualify for 5 and 7.5% rates.

The impact of the percentage depletion allowance on coal production is changing. The rising price of imported oil has increased the average price of all oil. Coal has been substituted for oil, resulting in dramatic coal price increases. The price increases will probably increase the effective 6% rate currently to nearly the statutory limit of 10% in the near future.

Percentage depletion may not exceed 50% of net income from the property. This limitation is known as the "net income limitation." The total cost which can be recovered by percentage depletion allowance is not limited to the cost of the property.

The other depletion method--cost depletion--resembles depreciation based upon the number of units produced. (The share of the original cost of the estimated total production--over the lifetime of the well or mine--which is produced in that year.) Using cost depletion, capital recovery cannot exceed the initial cost.

Percentage depletion usually results in a faster recovery than cost depletion, and the cost may be recovered many times over since percentage depletion is not limited to original cost.* Until recently, practically all depletion by the oil and gas industry was taken as a percentage depletion rather than cost depletion. Expenses of dry holes, intangible drilling costs (if expressed), and tangible drilling costs can all be deducted in addition to percentage depletion.

Impacts of percentage depletion include: (1) decrease in the price of qualifying oil, natural gas and other minerals indirectly encouraging consumption; (2) the bidding "up" of the price of drilling and mineral rights; and (3) encouragement of the development of new deposits resulting in production increases.

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* Professor J. Reid Hambrick estimated in testimony before the Ways and Means Committee (February 1973) that percentage depletion deductions amount to 16 times original cost.

Estimated Revenue Loss
(In Millions of Dollars)

Fiscal Year	Individuals	Corporations	Total
1977	575	1,020	1,595*
1976	500	1,080	1,580*
1975	465	2,010	2,475*
1974	--	--	N.A.**
1973	--	--	1,700**
1972	--	--	985**
1971	--	--	980**
1970	--	--	1,470**

* Gravelle,Jane, et al., Tax Expenditures: Compendium of Background Material on Individual Provisions, Prepared for U.S. Senate Committee on the Budget, March 17, 1976 (p. 31).

** Douglas, Lee, et al., Federal Subsidy Programs, Prepared for Joint Economic Committee, October 18, 1974 (p. 101).

Prior to 1975, oil and gas accounted for the bulk of percentage depletion. Since the 1975 repeal of percentage depletion for most oil and gas production, approximately 75% of current domestic gas and oil production is not eligible for this deduction. This will result in a reduction in revenue loss by the U.S. Treasury in the form of tax revenues beginning in 1976 as shown in the chart above. The sales of all other mineral deposits are unaffected.

b. Expensing of intangible drilling, exploration, and development costs: Certain expenses incurred in drilling for oil and gas can be deducted (or expensed) from taxable income. The intangible drilling costs required to bring a well into production include items such as labor, material, supplies and repairs. (Tangible expenses are those for assets such as tanks and pipes recovered through depreciation.) Costs incurred in mining activities for exploration and development may also be "expensed."

The advantage in "expensing" these costs involve the structure of the tax laws. Usually, expenditures designed to improve assets that yield an income steam for several years must be capitalized and deducted over the period in which the assets produce income. The tax advantage of treating these expenditures as current expenses is the same as any other allowing premature deductions; the taxpayer is allowed to defer current tax liabilities; this treatment amounts to an interest-free loan. The estimated impact of this special tax provision in terms of tax revenue loss by the U.S. treasury is shown in the chart below.

Estimated Revenue Loss
(In Millions of Dollars)

Fiscal Year	Individuals	Corporations	Total
1977	195	840	1,035*
1976	155	650	805
1975	120	500	620

* Gravelle, Jane, et al., Tax Expenditures: Compendium of Background Material on Individual Provisions, Prepared for U.S. Senate Committee on the Budget, March 17, 1976, p. 27.

These expensing provisions are additional benefits which supplement the special percentage depletion allowance extended to the mineral industry. Although the expensing and depletion provisions operate somewhat independently, a firm or person may be eligible for both and receive their combined benefits.

c. U.S. tax credit for payments to foreign governments: In addition to the tax benefits already mentioned, a foreign tax credit is alleged to provide special benefits for oil producers. Starting with the Revenue Act of 1918, the U.S. has allowed a foreign tax credit against income derived from foreign sources. This foreign tax credit has been particularly useful to the major oil companies who have historically accounted for almost half of the credits claimed by U.S. corporations. This credit is important because it is applied dollar for dollar against U.S. tax rather than the usual 48% for each dollar deduction applied to gross income as reported.

The impact of tax treatment of oil and gas companies' earnings abroad can be measured in terms of annual revenue lost by the U.S. Treasury in three general areas:1/

1. Allowance of percentage depletion (more technically, the excess of percentage depletion over cost depletion). . .approximately $50 million annually.

2. The use of excess foreign tax credits on income form oil and gas production to offset U.S. tax on other foreign source income. . . approximately $300 to $400 million annually.

1/ Energy Taxation: Possible Modifications in the Tax Treatment of Foreign Oil and Gas Income, Prepared by the Staff of the Joint Committee on Internal Revenue Taxation, February 21, 1974. (These dollar estimates are based on conditions existing during the early 1970's.)

3. The deducting of foreign development costs against U.S. source income. . . approximately $150 million annually.

d. Summary: The oil and gas industry are subject to special tax provisions which create benefits in at least the three ways described. First, the provisions allow, through the percentage depletion additional deductions beyond the recovery costs, and thus reduce taxes. Second, the provisions allow the acceleration of deductions for the cost of capital assets and thus defer taxes. And thirdly, the use of foreign tax credits reduces the U.S. tax liability by an amount equal to the taxes paid foreign countries.

2. Legislative history: This section outlines the history of the special tax provisions. It also specifies the tax rate at the time of enactment for both individuals and corporations (when possible) to illustrate the increased importance of the special provisions due to current higher tax rates, as well as the revision of the provisions themselves.

a. Depletion allowance:[1,2/] No allowance was made for depletion or for depreciation until the enactment of the 16th amendment in the 1913 law which established federal income tax. This provision allowed for reasonable deductions for exhaustion, wear and tear of property, in the case of mines not to exceed 5% of gross value of output.

The first major revision occurred in 1915 (the Revenue Act) in the allowance of depletion to be used at fair market value within 30 days of discovery. The most important aspect of discovery depletion was that it allowed deductions in excess of original cost.

In 1924, the depletion allowance was revised to limit deductions to 50% of net income from property. A further revision accompanied the Revenue Act of 1926 when a 27.5% depletion rate was adopted. This rate remained relatively unchanged until 1969. (Note at the time of its passage (1926), statutory tax rates for corporations were 13.5%, and ranged from 1.125 to 25% for individuals.)

In 1932, a provision was added requiring the basis of cost depletion to be reduced by any percentage depletion taken. In 1954, a provision allowing aggregation of mineral interests within an operating unit for purposes of the 50% of taxable income limitation was adopted.

1/ Agria, Susan, "Special Tax Treatment of Mineral Industries," in The Taxation of Income from Capital, The Brookings Institution, Washington, D.C., pp. 77-122 (1969).

2/ U.S. Congress, Senate Committee on Interior and Insular Affairs, An Analysis of the Federal Tax Treatment of Oil and Gas and Some Policy Alternatives, 58 pages (1974).

The 1969 Tax Reform Act made several changes affecting depletion. Its major revision was the reduction of the depletion rate to 22%. In 1970, excess depletion was made subject to the minimum tax. (Note, at the time these revisions in the tax laws were made, statutory tax rates for corporations were 48%, and ranged from 14 to 70% for individuals.) This was further revised in 1975 as already described earlier.

The House Report accompanying the Tax Report Act of 1969 described the change to depletion allowance in the following manner.1/

> ". . . committee believes that even if percentage depletion rates are viewed as a needed stimulant at the present time, they are higher than is needed to achieve the desired beneficial effect on reserves."
>
> "Your committee believes that there is a need to strike a better balance than now exists between the objectives of encouraging the discovery of new reserves and the level and revenue cost of percentage depletion allowances. The present 27.5% percentage depletion rate for oil and gas wells was set in 1926 when tax rates were substantially lower than at present. As a result, the tax-inducement granted by this percentage depletion is substantially greater than it was in 1926."

b. Expensing of intangible drilling, exploration and development costs:2,3/ The option to expense intangible drilling costs (as well as dry hole costs) of oil and gas wells developed through regulations issued in 1917.4/ The regulations reflected the view that such costs were ordinary operating expenses. In 1942, the Treasury Department recommended that the provisions be removed, but Congress did not consider the suggestion.5/ In 1945, when a court decision invalidated the regulations,6/ Congress adopted a resolution7/ approving the treatment and later incorporation into law in the 1954 code. The legislative history of this resolution

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1/ U.S. Congress, Committee on Ways and Means, report on the Tax Reform Act of 1969, 91st Congress, 1st Session, House Report 91-413, pt. 1, p. 137 (1969).

2/ Agria, op. cit., pp. 77-122.

3/ U.S. Congress, Senate Committee on Interior and Insular Affairs, An Analysis of the Federal Tax Treatment of Oil and Gas and Some Policy Alternatives, 58 pages (1975).

4/ 19 Treas. Dec., Int. Rev. 31 (1917).

5/ Hearings on Revenue Revision of 1942 before the Committee on Ways and Means, p. 2996, Vol. 3, 77th Congress, 2nd Session.

6/ FHE Oil Co. vs. Commissioner, 147 F. 2nd 1002, 5th Cir. (1945).

7/ H. Con. Res. 50, 79th Congress, 1st Session.

indicates the tax provision was intended to reduce uncertainty in mineral exploration and stimulate drilling for military and civilian purposes.1/ Expensing of mine development expenditures was enacted in 1951 to reduce ambiguity in current tax treatment and encourage extraction. A provision for exploration was added in 1966.

Prior to the Tax Reform Act of 1969, a taxpayer could elect either to deduct without dollar limitation exploration expenditures in the United States, which subsequently reduced percentage depletion benefits, or to deduct up to $100,000 a year with a total not to exceed $400,000 of foreign and domestic exploration expenditures without the application of the recapture rule. The 1969 Act subjected all post-1969 exploration expenditures to recapture.

c. Foreign tax credit:2/ The first foreign tax credit was allowed for foreign income, war and excess profits tax in the Revenue Act of 1918 for the purpose of alleviating the burden of high foreign taxes.

The original act of 1913 allowed foreign income taxes to be deducted but not credited. There were no limits to the credit, allowing the amount of foreign income taxes as a deduction reducing U.S. taxes on domestic income. The Revenue Act of 1921 provided an offsetting limitation on domestic income against which foreign taxes could be applied.

The Revenue Act of 1932 added a per county limitation, so taxpayers were subject to two limits on foreign tax credits. In addition, prior to 1932 any taxes which could not be credited under the foreign tax credit procedures were allowed as a deduction, thereby reducing the tax liability on domestic income. The 1932 act disallowed any deduction of the credit taken. (Note in 1932 individual tax rates were up to 63%, and the corporate tax rate was 13.75%.)

The Revenue Act of 1942 added a provision allowing taxes in lieu of income taxes to be included in the foreign tax credit. This action was taken because some countries tended to impose excise rather than income taxes.

In 1950, the Treasury recommended removal of the overall limits on the grounds that it reduced allowable taxes if losses were sustained in one country and created barriers to investment.

1/ H. Rep. No. 761, 79th Congress, 1st Session, pp. 1-2.
2/ Agria, op. cit., pp. 77-122.

The Technical Amendments Act of 1958 introduced a 2-year carry-back and 5-year carry-forward. The provisions were included in the House report which indicted that loss of credits occurred because of different reporting requirements.

In 1960, a separate bill was passed (P.L. 86-780) allowing taxpayers to choose between the overall and per-county limitation. (Note at this time, and in 1958, the maximum statutory individual income tax rate was 91% and the corporate income tax rate 52%.)

d. Summary: All of these provisions date back to the earliest income tax laws. In view of the greatly increased tax rates for corporations and the development of higher foreign taxes, these provisions account for a much larger benefit in present times than at the time they were enacted. A deduction currently reduces tax liability for corporations 48¢ on the dollar; in 1926 it would have reduced tax liability 13.75¢; in 1918 it would have reduced tax liability 2¢ on the dollar.

3. Quantitative studies: Relatively little quantitative information concerning the impact of special tax provisions for the energy industry exists. The available studies attempt to evaluate and quantify the dollar impact in revenue loss to the U.S. Treasury of (1) percentage depletion, and (2) intangible drilling expense. A more comprehensive review of such studies was prepared in 1974 by Dunn and Gravelle.1/

The first major quantitative study--the CONSAD Report2/, prepared in 1968--estimated the effects of tax incentives. It attempted to measure the impacts of repealing percentage depletion and expensing of intangibles. The study utilized an industry simulation mode and concluded that the existing tax provision had little impact on oil reserves, and that $1.4 billion in revenue loss through these special tax provisions yielded $150 million in reserve additions.*

1/ U.S. Congress, Senate Committee on Interior and Insular Affairs, An Analysis of the Federal Tax Treatment of Oil and Gas and Some Policy Alternatives (1974).

2/ CONSAD Research Corporation, The Economic Factors Affecting the Level of Domestic Petroleum Reservers, pt. 4 of the U.S. Congress Committee on Ways and Means, and Senate Committee on Finance, Tax Reform Studies and Proposals, U.S. Treasury Department, Washington, Government Printing Office (1969).

* The CONSAD data and methodology have been subject to strong criticism by several industry sources, the main (or most serious) criticism being that production was held constant.

A second more detailed study was prepared by Spann, Erickson and Millsaps.1/ This analysis of the impacts of these special tax provisions was based on existing estimates of supply responsiveness in the petroleum industry.2/ Their model allowed production and the reserve ratio to vary along with the supply of reserves, thus avoiding some of the criticisms of the CONSAD study. They measured the effects of removing percentage depletion and the expanding intangible expenses, assuming in one case a constant ratio of imports with increased prices, and in the other, imports sufficient to keep the prices constant. They found a substantial impact of tax provisions in terms of inefficiency in the allocation of resources, which they estimated at $306.5 million. The results also suggested the per barrel cost of an emergency storage reserve would be less than the cost of additional reserved and production encouraged by tax provisions, if the goal of the provisions was to provide for national security.3/

It should also be noted that the results are dependent upon the data and methodology used, including critical assumptions concerning supply and demand elasticity. Thus, the estimates are subject to dangers associated with elasticity measures. Elasticity measures are likely to vary depending upon the amount of price increase or decrease being considered. In addition, in using these results for policy purposes, the price constraints deriving from imports may not be so significant as the authors suggested (1) if the price of imported oil increases; (2) if the exporting countries limit supplies; or (3) if prices are administered so as to present no competition with domestic suppliers. The estimate of revenue loss provided in this study--$2.5 billion--is larger than the CONSAD estimate.

The results of these studies are summarized in Table E-II. While the different studies fail to derive the same answer, they all do suggest that the cost of the special tax provisions, particularly percentage depletion, may involve tax losses significantly larger than the gain in reserves, production or both.

1/ Spann, Robert M., Edward Erickson and Stephen W. Millsaps, "Percentage Depletion and the Price and Output of Domestic Crude Oil," in U.S. Congress, House Ways and Means Committee, panel discussions on general tax reforms, Panel 9, Natural Resources, pp. 1309-1328, February 25, 1973.

2/ The study refers to the estimates by W. V. Meid and P. E. Sorenson in "A National Defense Petroleum Reserve Alternative to Oil Import Quotas," Land Economics, 47(3) (August 1971), which estimated a per barrel cost as low as 9¢. The study estimated per barrel cost for tax provisions may be as high as 20 to 30¢/barrel.

3/ Spann, Erickson, Millsaps, op. cit.

TABLE E-II

QUANTITATIVE STUDIES OF EFFECTS OF REMOVING TAX PROVISIONS ON DOMESTIC OIL PRICES, PRODUCTION, AND RESERVES (DOLLAR AMOUNTS IN MILLIONS)

Study	Prices (%)	Production (%)	Revenues (%)	Value of Production a/	Tax Revenue Loss
1. CONSAD Research Corp., 1968, for years 1950-1965					
Percentage Depletion	N.A. b/	N.A. c/	- 3.0	--	$1,200
Intangible Drilling Costs	N.A.	--	-1.9 - 4.0	--	$119 - $324
Both	N.A.	--	- 7.0	--	$1,400
2. Spann, Erickson, and Millsaps, 1973, for year 1971					
Percentage Depletion	9.0	(-4.3) - (-11.4)	(-11.2) - (-22.5)	$ 503 - $1,333	--
Intangible Drilling Costs	14.0	(-6.2) - (-16.3)	(-15.1) - (-31.4)	$ 725 - $1,906	--
Both	24.4	(-10.5) - (-26.0)	(-24.4) - (-36.0)	$1,227 - $3,040	$2,500

a/ Dollar values for the Spann, et al., study were computed by multiplying the value of U.S. crude oil production (BOM) by the percentage change in respective estimates of production.

b/ Prices were held constant.

c/ Production was held constant.

C. Import Controls and National Security

1. Description: The benefits provided by import quotas to the petroleum and nuclear segments of the energy industry have been substantial. The impact on the nuclear industry is discussed in Section D. The remainder of this section briefly traces the history of the various oil import quota programs and estimates their impacts. Several government-sponsored studies have indicated the direct impacts of such programs on oil costs to range from 25 to 45%.

2. History of oil import quota schemes:1/ Oil import quota schemes have been the subject of controversy among policymakers and economists during the last 3 decades. A landmark in these policy discussions was the Report of the Cabinet Task Force on Oil Import Controls issued in February 1970. This report outlines the nature of the price differential between imported and domestic oil and the size of the subsidies paid by the American consumer in the form of higher costs attributable to the imposition of import quotas.

The first oil import quotas were enacted in the 1930's. Through 1959 these programs were voluntary and generally ineffective. In 1959, the Mandatory Oil Import Quota Program* was enacted. This program was established on the grounds "that crude oil and the principal crude oil derivatives and products are being imported in such quantities and under such circumstances as to threaten to impair the national security." The program's objective was to eliminate U.S. dependence on foreign oil supplies. Its goal was to encourage the domestic oil industry to locate and develop domestic resources through a series of import restrictions. In addition, it was "to prevent imports from causing a decline that would so weaken the national economy as to impair the national security."

The Mandatory Program contained two separate regionally-administered schemes: one for that portion of the U.S. east of the Rockies; the other for the portion west of the Rockies.

1/ Dam, Kenneth W., "Implementation of Import Quotas: The Case of Oil," Journal of Law and Economics, January 1971, pp. 1-60.

* Many attribute the U.S. refining shortage and political vulnerability to the Mandatory Oil Import Quota Program. There are two lessons to learn. First, the costs of society when government enters into a market and reduces competition may be far greater than the wedge in relative prices that it creates. Lost jobs, a reduced national security posture, the lack of adequate refining capacity are the additional factors which can be attributed to this program. Secondly, the whole world is paying a higher price for oil in part due to the lack of competition created by the program.

The administrative policies concerning the quotas ("tickets") were allocated as a percent of refinery inputs, subject to two modifications, a swap arrangement and a finagle factor. These modifications could be manipulated through use of (1) a sliding scale; (2) historical minimums; (3) exchanges or manipulations of allocation computations. These procedural elements become further complicated with a web of "exemptions" and preferences" that would delight lawyers and confound the public. For example, overland shipments from Canada or Mexico formed a quota exemption.

During the summer of 1973, two significant events altered U.S. oil import control programs. First, a presidential announcement ended the Mandatory Oil Program. A few months later, the Middle East war erupted and the U.S. was held at political bay by the world's oil producers.

3. Quantitative studies: Only two studies have attempted to estimate the social and subsidy costs associated with the Mandatory Oil Program. Each evaluation calculated the added costs paid by U.S. consumers to domestic oil companies attributable to these artificial import controls.

The first study[1/] performed in the early 1960's by the President's Petroleum Study Committee and later updated by Resources for the Future calculated the Mandatory Program increased oil prices approximately $1.00/ barrel. At consumption rates existing during the later 1960's, this amounted to a $3.5 billion subsidy paid by U.S. consumers. This translates into a 25% subsidy in the form of added consumer prices paid to the domestic oil companies.

A 1973 study by Cicchetti and William Gillen[2/] calculated both social and subsidy costs in 1970 associated with the Mandatory Oil Import Quota Program to be $224 billion, and $720 billion, respectively. The social costs contained two components reflecting the economic inefficiency (or misallocation of resources) caused by the quota program.

> "Component One consisted of those costs of supplying the quantity consumed with the quota system in effect over the cost for the same quantity which would have been imported at a lower price. This equates those costs equal to the amount of resources that are needlessly expended to produce the same quantity of crude oil."

1/ A Report to the President, by the Petroleum Study Committee, op. cit., 1968.

2/ Cicchetti, Charles J., and William Gillen, "The Mandatory Oil Import Quota Program: A Consideration of Economic Efficiency and Equity," in The Economics of Federal Subsidy Programs, U.S. Congress, Joint Economic Committee, Washington, U.S. Government Printing Office, p. 1013.

"Component Two calculated the social costs incurred from foregone consumer surplus. It calculated the cost of increased consumption that would have resulted if oil prices had been competitive. This is a lost opportunity cost to society."

The size of the subsidy was estimated in added consumer prices paid to domestic oil companies and calculated as the cost differential per barrel between domestic and foreign oil prices multiplied by total domestic consumption.

D. Federal Subsidy Programs and Nuclear Power Industry

The federal government has actively supported the development of several energy industry segments. For example, the nuclear power industry has been directly or indirectly subsidized since 1946. The history of the hydroelectric industry serves as another example illustrating how government subsidies have supported the development of a segment of the energy industry. In both cases--government agencies (e.g., the AEC, ERDA, TVA, Department of Interior, etc.) have initiated programs aimed at (1) obtaining the basic scientific and engineering data needed for proof of technical feasibility and safety; (2) demonstrating the actual economic feasibility of energy production systems; (3) funding and/or performing industry R&D; and (4) purchasing, constructing or operating facilities for several industry segments.

The present development of the hydroelectric industry has been the direct result of the federal government's direct support of the industry. Since 1909, the government has constructed and operated the major hydroelectric facilities in the United States.

Government participation in the development of nuclear energy has been large and recent, compared to other conventional energy sources (e.g., coal, oil and natural gas). Many of the factors which influenced the development of nuclear energy may also influence solar energy development. Therefore, the remainder of this appendix involves a detailed discussion of the role government subsidies have played in the development of the nuclear energy industry.

Nuclear power is unique among the energy industries because it has been the product of governmental action since its inception during World War II. In fact, nuclear power has had a situation which is almost totally opposite to that prevailing in other energy industries, i.e., public policy issues regarding the application of nuclear power have centered on the degree to which nuclear energy should be released from governmental control and permitted to become part of the free enterprise system. The more normal route is for an energy industry to begin in the private sector, with governmental intervention resulting from a need for either regulation or assistance.

Federal responsibility for the development of civilian uses of nuclear energy was recognized by Congress in the Atomic Energy Act of 1946.1/ These responsibilities were clarified and broadened in the Atomic Energy Act of 1954.2/ The Act of 1946 placed the responsibility for nuclear power development with the Atomic Energy Commission (AEC). The AEC embarked on programs aimed at (1) obtaining the basic scientific and engineering data needed for proof of technical feasibility and safety of nuclear power generation and (2) demonstrating the actual economic feasibility of nuclear reactors for the generation of electricity.

In 1953, the AEC, with the encouragement of the Joint Committee on Atomic Energy, began a 5-year "experimental" program to develop promising reactor concepts. Construction was started on several power-producing reactors on AEC sites, and one AEC build and owned reactor provided steam to an evestor owned utility (Shippingport, Pennsylvania). The utility built the power generating equipment and operated the reactor under contract with the AEC.

The revision of the Atomic Energy Act in 1954 resulted in the continued expansion of the nuclear program by both government and industry. Most significant was the cessation of the government's monopoly of nuclear reactor ownership. For the first time, private industry was permitted to own and operate nuclear reactors. However, the 1954 Act still retained government ownership of all fissionable material. Private operators could obtain fissionable material only on lease from the federal government. Also, any fissionable material generated within the reactor was, by law, government property for which they paid a "fair value."

In 1955, a "Power Demonstration" program was added.3/ Under this program, the AEC and participating utilities cooperated in constructing and operating nuclear power plants on the utility grid. Two options in this program were (1) for the utility to purchase the steam from the AEC reactor or (2) for the utility to be given R&D assistance in designing and constructing their own reactor while no charge was made for the lease of the government owned nuclear fuel.

In 1962, the AEC (by request) submitted to the President of the United States, a report on the state of the civilian nuclear power program.4/ As stated in this report:

1/ PL-585: 79th Congress.

2/ PL-703: 83rd Congress

3/ U.S. Atomic Energy Commission, "Civilian Nuclear Power: A Report to the President-1962," November 1962.

4/ Ibid.

"The overall objective of the Commission's nuclear power program should be to foster and support the growing use of nuclear energy, and importantly, to guide the program in such directions as to make possible the exploitation of the vast energy resources latent in the fertile materials, uranium-238 and thorium."

More specifically, the objectives outlined in the 1962 report were:

- "The demonstration of economic nuclear power by assuming the construction of plants incorporating the presently most competitive reactor types;

- The early establishment of a self-sufficient and growing nuclear power industry that will assume an increasing share of the development costs;

- The development of improved convertor and, later, breeder reactors to convert the fertile isotopes to fissionable ones, thus making available the full potential of the nuclear fuels;

- The maintenance of U.S. technological leadership in the world by means of a vigorous domestic nuclear power program and appropriate cooperation with, and assistance to, our friends abroad."

In 1964, the Private Ownership of Special Nuclear Materials Act[1/] was passed. This Act provided for a transition period, during which time the ownership of nuclear fuel would be transferred from the federal government to private parties. Part of this legislation established a "buy-back" policy by guaranteeing a purchase price for plutonium and uranium-233. This "buy-back" policy has assured a purchase price for these materials since the 1950's. The prices were set at an estimated fuel value of $10/g of plutonium and $14/g of uranium-233. The "buy-back" program ended in 1970, even though plutonium cannot yet be used as a reactor fuel. It has been estimated that in a typical pressurized water reactor the fuel cost would be increased by 12% if its generated plutonium had no value.[2/]

The 1964 law also authorized the AEC to provide total enrichment services whereby raw materials can be purchased on the open market, processed in privately owned plants, enriched in the government owned gaseous diffusion plants, and converted into fuel elements under private contract. This improved the overall outlook for the uranium mining and milling industry, as

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1/ PL-489: 99th Congress.

2/ Haley, J., "End of AEC Buy-Back; Beginning of Commercial Plutonium Recycle," Westinghouse Electric Corporation, Nuclear Energy Systems, 1971.

evidenced by the firming prices and signing of contracts for the delivery of uranium feed following 1967.[1] The availability of the enriching service also encouraged the user of nuclear power abroad and the subsequent sale of U.S. designed reactors using enriched uranium.

A more recent program by the government to transfer nuclear technology to private enterprise involves the next generation of uranium enrichment facilities. Legislation written by the Energy Research and Development Administration (ERDA) and proposed by Senator John Pastore and Representative Melvin Price, the "Nuclear Fuel Assurance Act," will permit ERDA to assist private industry in this extremely capital intensive venture. Under the proposed Act, ERDA will "assist private industry to finance, construct, and operate all future uranium enrichment facilities to meet the projected fuel requirements for civilian nuclear power plants."[2]

The following discussion presents a summary review of some of the governmental actions on several categories. This is not intended to be a comprehensive listing of all government programs, but rather is an indication of the types of actions that have been pursued.

Fuel Cycle - All phases of the nuclear fuel cycle have been subsizided at some time. Mention has already been made of the effect of total enrichment on the mining and milling industry. Another "subsidy" that occured was a pricing action by the AEC. In order to encourage the emergence of a viable domestic uranium market, the AEC based its enriched uranium sale or lease charge schedule on $8/lb of U_3O_8 from 1958 through 1966 (plus a stretch-out period). This price was considerably above the market price of $5 to $6/lb. The current price is slightly over $10/lb with an anticipated price of $19.20/lb in 1982 (constant 1975 dollars). Through a series of bonuses and guarantees of long-term contracts, the uranium industry was built from almost nothing in 1950, to a point where the U.S. is virtually self-sufficient in this field.

Other measures designed to stimulate the domestic uranium industry included an embargo on the enrichment of foreign uranium for domestic use.[3] This embargo was introduced for the expressed purpose of permitting the domestic industry to survive during the 1960's.

The nuclear fuel leasing policy permitted under the Atomic Energy Act of 1954 allowed the utility industry to enjoy several advantages. These were:[4]

1/ U.S. Atomic Energy Commission, "Civilian Nuclear Power: The 1967 Supplement to the 1962 Report to the President," February 1967.
2/ The Budget of the United States Government-Fiscal Year 1977.
3/ "Annual Report to the Congress of the Atomic Energy Commission for 1966," January 1967.
4/ U.S. Atomic Energy Commission," Civilian Nuclear Power: The 1967 Supplement to the 1962 Report to the President," February 1967.

- The cost to industry of enriched uranium was lower than could have been obtained by industry alone because of the government owned enrichment plants;

- The lease charge rate for the fuel inventory was less than carrying charges under private financing; and

- It was not necessary for a utility to raise the large amount of capital required for the fuel inventory at a time when the utility had to raise funds for plant construction.

The overall effect of not requiring the private ownership of nuclear fuel was to stimulate the nuclear industry.

The uranium enrichment phase of the nuclear fuel cycle has always been subsidized. This is primarily due to the requirement for security of the operating parameters involved in the production of weapons grade material. Under Section 161v of the Atomic Energy Act of 1954, the AEC in 1966 established a "ceiling" of $30/kg unit of separative work (actual price was $26 in 1967). However, there was no attempt by the government to recover the true costs of enriching the uranium. When it was decided by the federal government to recover the cost of enrichment during the early 1970's, the price per separative work unit increased substantially. The current price for uranium enriching services is $53.35 per separative work unit, with an increase to $76 if the proposed Nuclear Fuel Assurance Act becomes law.

Radioactive waste disposal is an area that has recently received much attention from the federal government. Research and development on this subject have been carried on at Oak Ridge National Laboratory and other national laboratories. Currently, the government is assisting utilities in the ultimate disposal of radioactive wastes through storage and monitoring programs, as well as through the searching process for a permanent burial site.

In all of this complexity one fact is clear: The federal government (through the AEC and ERDA) has in the past operated as a nuclear fuel price administrator. It is not completely relinquishing this role so long as it continues to determine the price at which enrichment is performed. With the possibility of disposing of the government owned enrichment facilities, the real costs of the entire fuel cycle cost/price structure should be realized.

Reactor Development - The AEC's Power Demonstration Reactor Program has provided assistance for a number of light water reactor (LWR) power plants. (This is in addition to the initial development of the pressurized water concept both in the nuclear navy and at Shippingport.) A substantial sum of money continues to be invested in fission power reactor development, with the FY-1977 ERDA budget calling for $823 million.[1/] Some of the nuclear reactor concepts which have been directly subsidized by the government in the past are:

- Light water reactor
- Heavy water moderated reactor
- Light water breeder reactor
- High temperature gas cooled reactor
- Liquid metal fast breeder reactor
- Gas cooled fast breeder reactor
- Steam cooled fast breeder reactor
- Molten salt breeder reactor

The government's general reactor technology programs were conducted by private industry, universities and national laboratories. These programs covered almost all aspects of nuclear reactor design and construction activities. As such, these reactor development programs constituted an R&D subsidy of the nuclear industry.

Service Industries - In addition to the major equipment industry, a large and diverse service industry is required to implement a large-scale nuclear power program. These industries include the fabrication of fuels, nuclear reactor control equipment and the chemical processing of spent reactor fuel. Many of the service industries were given considerable business by the government (AEC) during the 1950's and 1960's.

Besides giving the service industries business, the AEC decided that under no circumstances should the government compete with these service industries for private business. Fortunately, because most of the service industries could start on a small scale, there was no risk of competition from the government. One exception to this was the processing of spent reactor fuel, where it would only be attractive to industry on a large scale. As part of the encouragement to private industry, the AEC informally promised business (to a limit of 100 operating days per year) to those who would enter the field.[2/]

Research and Development Programs - In bringing the civilian nuclear power program to its present stage, the federal government has carried out a national research and development program. The scope of this program has purposely been kept very broad.

1/ "Appendix to the U.S. Budget for Fiscal Year 1977."

2/ U.S. Atomic Energy Commission, "Civilian Nuclear Power: A Report to the President-1962," November 1962.

The primary justification for the expenditure of large amounts of money in nuclear reactor research and development, even after commercial nuclear power has been achieved, is based on the following line of reasoning. The class of reactors that are currently being constructed (LWR) is extremely inefficient in its use of nuclear raw materials. The goal of achieving more efficient resource utilization has been the primary driving force behind the large research and development program. Both convertor reactors and breeder reactors have been developed, with the main focus, until the recent energy policy change, being on the LMFBR.

Future government R&D expenditures on nuclear energy are currently under debate. Uranium is only one of several fuels that can be used to generate electricity. Decisions concerning the research and development program that are motivated by a concern for the efficiency of the utilization of uranium cannot be properly evaluated except in the context of a consideration of the supply, demand and net energy efficiency of all fuels used in generating electric energy.

The research and development program has included work in national laboratories and other government owned facilities, primarily at governmental expense. It has included:

- Basic and applied research in physics, chemistry and metallurgy;
- Development work on reactor components such as fuel elements, structural materials, moderators, coolants, heat exchangers, pumps, etc.; and
- Development of processes such as chemical reprocessing, fuel fabrication and waste disposal.

In addition to the basic research and development program, an extensive "Power Demonstration" program was pursued. This program, which has previously been discussed, was used to verify technology in actual practice, to yield economic information and to provide experience on which to base improvements.

Reactor Safety - The achievement of the objective for reactor safety requires the development of safety related technology, safety criteria, safety codes and standards, safety research and development facilities, and a program whereby safety considerations can be transferred to regulatory agencies. This work has been carried out almost exclusively with government funds in government facilities. Examples of the diverse nature of some of the safety features that have been investigated are:1/

1/ U.S. Atomic Energy Commission, "Civilian Nucmear Power: The 1967 Supplement to the 1962 Report to the President," February 1967.

- Emergency core cooling systems
- Detection of incipient cracking in reactors piping and vessel materials
- Methods of scavenging radioactive gases in containment buildings
- Tests to determine plant component and instrumentation reliability
- Development of sodium-cooled reactor loops
- Fault-free analysis safety studies
- Siting related problems

Much of the current expenditures in reactor safety are being directed toward solving safety problems of the advanced reactors (primarily the LMFBR).

Nuclear Insurance - The Price-Anderson provisions of the Atomic Energy Act of 1954, with amendments, afford protection to the public and to licensees and contractors from the risks associated with atomic energy. Price-Anderson provisions provide for a program of private insurance and governmental indemnity amounting to a maximum of $560 million to cover damages that conceivably could arise from a nuclear incident.

The insurance pool (Nuclear Energy Liability-Property Assurance Association) will insure a single nuclear power reactor (or fuel reprocessing plant) for $175 million on the facility and $125 million for public liability. A system of fees and purchased government insurance extend this to the $560 million (which will reach over one billion dollars by 1990).1/ Federal law requires Congress to "take whatever action" is necessary should consequences exceed this liability provision.

Some of the aspects of the various governmental subsidies to the nuclear power industry have been discussed. It is worthwhile to attempt to determine the results of these subsidies. One measure of the success of the overall program is to examine the installed nuclear capacity over the past 25 years in relation to the amount of government funding. The success of the program must also be measured against the stated objective:

1/ "Nuclear News," February 1976.

"Thus, the proper role of government is to take the lead in developing and demonstrating the technology in such ways that natural economic forces will promote industrial applications and lead to a self-sustaining and growing nuclear power industry; the program should be guided in such directions that those economic forces will work toward ends in the public interest, including the long-range conservation of both our fossil and our nuclear fuel resources.1/

One approach to assessing the results of the various governmental subsidy programs is to determine the cumulative funding level in relation to the installed nuclear capacity as a function of time. The same techniques can be applied to the amount of electric energy generated by the nuclear plants.

It was decided to use information from the appendices to the U.S. Budget for fiscal years 1956 to 1977 as the source of governmental expenditures. All figures prior to 1976 are actual expenditures, while those to 1985 reflect a budget approximately equivalent to the projected 1977 budget. This may not be too far in error, as historical data indicate that federal programs seldom make sudden large changes in funding, but rather tend to increase or decrease gradually over a period of years.

Information gathered on the installed nuclear generating capacity was taken from the Nuclear News "World List of Nuclear Power Plants" (February 1976 issue). Due to the long lead times required for the construction and licensing of a nuclear power plant, there is not a great deal of variation from this schedule which can reasonably be anticipated (barring a nuclear moratorium).

The quantities of electric power generated from nuclear facilities were taken from the Edison Electric Institute publication, "Statistical Year Book of the Electric Utility Industry for 1973." Following the year 1975, projections of the energy produced from nuclear reactors were based on an assumed 60% load factor (in keeping with the past year or two of operating data). It was assumed that no nuclear power plants currently operating would be retired prior to 1985.

An attempt was made to segregate the funds expended by the AEC/ERDA/NRC into three categories: research and development programs, direct subsidy programs, and nuclear weapons related programs. Because of the secrecy involved in the weapons industry, it is almost impossible to completely separate this category from the others. For example, what portion of the expenditures in the area of uranium enrichment should be attributed to the

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1/ U.S. Atomic Energy Commission, "Civilian Nuclear Power: A Report to the President-1962," November 1962.

private industry category and how much to weapons? The solution to this type of problem was to assign an arbitrary (but conservative) fraction of the expenses to each category.

The R&D programs included the following portions of the yearly budget:

- Reactor development (including nuclear safety)
- Physical research
- Biology and medicine research
- Isotope development (later replated by "applied energy technology").

The direct cost category included part of the following portions of the yearly budget:

- Procurement of raw materials
- Special nuclear materials (enrichment)
- Training, education and information
- Program administration
- Regulations
- Program support
- Plant construction and capital equipment
- Credit for money received from private industry for lease of nuclear materials, uranium enrichment, waste disposal, etc.

It was recognized that some fraction of the direct costs should be related to the nuclear weapons effort. It was decided that the categories of (1) training, education and information, and (2) regulations were wholly within the area of a direct cost subsidy to the nuclear power industry. All of the remaining programs within the direct cost category were allocated 50% for weapons and 50% for the nuclear power industry. This is probably a conservative estimate, in that it probably overstates that portion which is allocated to weapons.

A cautionary note should be added to this point to explain that the absolute results of the analysis are not without uncertainty. The extremely large numbers calculated tend to make the results less believable. However, it is felt that the method of analysis used does present the basic facts of the case: namely, that the nuclear industry has been, and continues to be, heavily subsidized.

Figures E-1 and E-2 illustrate the results of the analysis. Table E-III presents the inputs and the calculations used in the figures. In Figure E-1 the cumulative amount of money invested by the federal government is distributed over the cumulative installed nuclear generating capacity as a function of time. The government's investment is in constant 1975 dollars. Both the R&D component and the direct cost component of the total subsidy are shown.

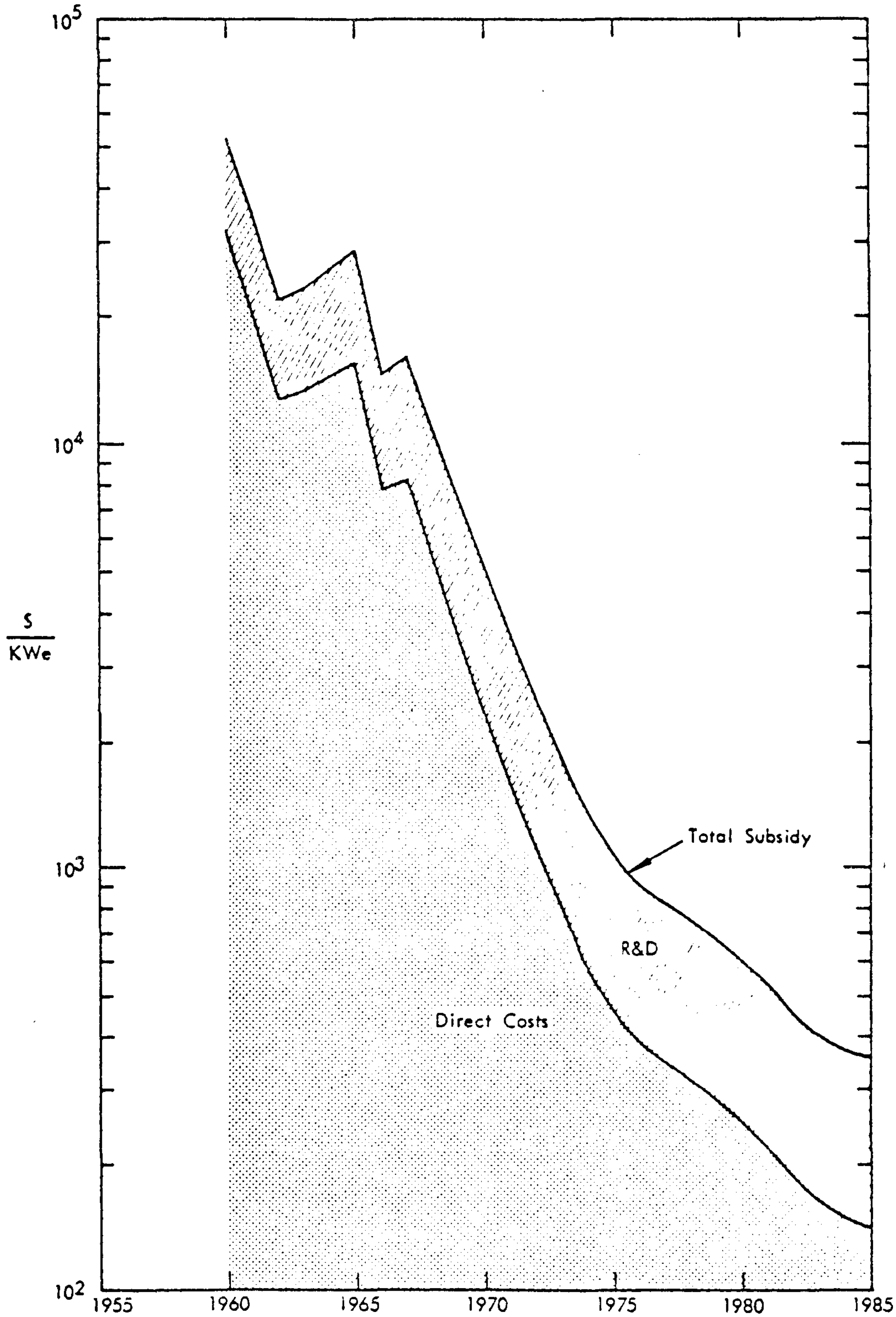

Figure E-1 - Cumulative Federal Subsidies to the Nuclear Power Industry Distributed Over the Cumulative Installed Nuclear Generating Capacity as a Function of Time

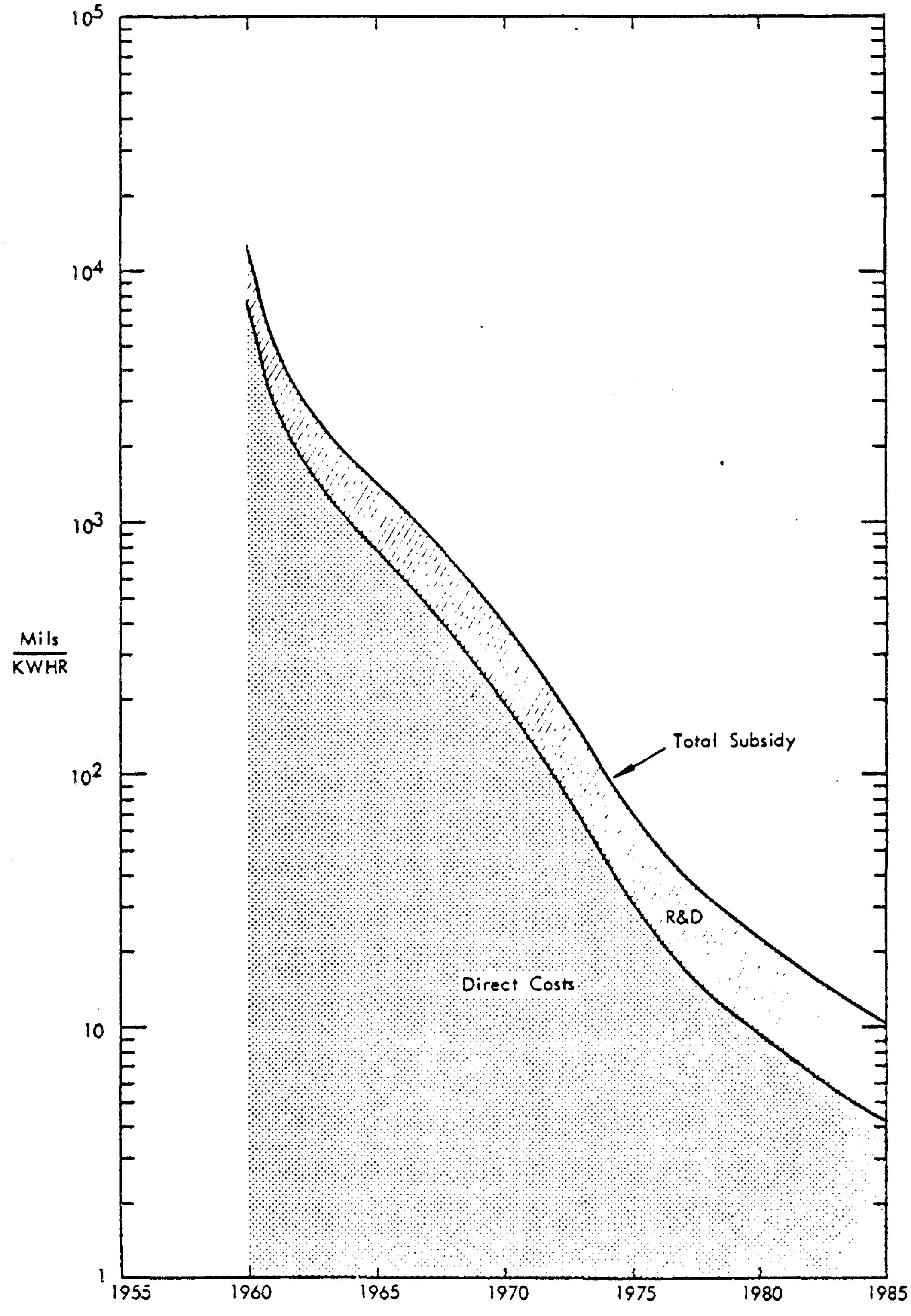

Figure E-2 - Cumulative Federal Subsidies to the Nuclear Power Industry Distributed Over the Cumulative Energy Generated by Nuclear Power Plants as a Function of Time

TABLE E-III

AEC/ERDA/NRC EXPENDITURES
(MILLIONS $)

Year	1 Procurement of Raw Materials	2 Special Nuclear Materials	3 Development of Nuclear Reactors	4 Physical Research	5 Biology and Medicine Research	6 Training, Education, Information	7 Isotope Development	8 Communities	9 Program Administration	10 Plant Construction and Equipment	11 Regulations
1956	281.0	553.1	171.2	49.5	28.4	4.7		18.8	35.3	131.5	
1957	397.8	581.6	266.6	59.3	31.5	7.8		17.8	38.0	201.4	
1958	598.6	567.7	309.0	90.6	35.3	15.5	0.0	17.7	45.9	164.7	
1959	705.5	541.3	347.1	114.6	42.0	13.0	3.1	16.5	49.4	254.3	
1960	715.9	553.3	387.4	135.3	47.6	11.8	3.8	14.2	50.6	267.0	
1961	634.6	560.4	424.4	161.0	52.9	13.2	4.2	9.1	58.9	211.7	
1962	537.2	491.1	396.7	159.6	58.3	12.7	5.2	8.4	59.3	280.3	
1963	477.7	477.9	462.4	182.8	65.1	14.0	6.1	8.9	65.0	356.8	
1964	326.2	463.7	502.3	195.8	71.0	15.0	7.9	9.3	70.8	218.1	
1965	261.0	393.0	477.5	212.6	77.1	15.5	8.8	8.2	77.9	258.5	
1966	206.2	373.2	428.6	234.5	82.4	15.6	7.0	7.9	81.9	211.1	
1967	161.9	349.3	455.0	253.4	85.7	15.9	6.9	9.3	87.5	199.9	
1968	125.3	340.1	491.1	264.7	88.1	16.1	7.3	6.5	94.3	137.4	
1969	100.9	328.7	443.4	273.9	88.8	16.3	6.7	6.3	96.2	259.2	9.3
1970		371.6	423.0	277.8	89.5	15.2	6.3	9.7	108.6	235.8	11.8
1971		362.2	428.4	270.8	88.1	12.9	6.5	7.8	116.8	289.1	15.7
1972		383.2	441.2	264.7	88.5					281.7	26.8
1973		429.5	477.9	280.9	111.4					369.8	45.3
1974		511.4	466.7	353.7	106.3					475.3	40.7
1975		467.6	571.4	482.8	134.6					525.3	53.2
1976		740.0	599.7	605.6	164.5					676.9	65.8
TQ		198.8	165.3	145.4	42.8					124.9	16.8
1977		1,011.9	802.3	684.6	174.7					1,005.6	76.6
1978		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1979		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1980		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1981		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1982		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1983		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1984		1,100.0	850.0	700.0	200.0					1,100.0	100.0
1985		1,100.0	850.0	700.0	200.0					1,100.0	100.0

TABLE E-III (Continued)

Year	12 Applied Energy Technology (7)	13 Program Support (6+8+9)	14 Installed Nuclear Capacity (Mwe)	15 Cumulative Capacity (Mwe)	16 Electricity Generated (10^9 kw-hr)	17 Cumulative Generation (10^9 kw-hr)	18 Government R & D Programs (10^6 \$)	19 Cumulative R & D Expenses (10^6 \$)	20 R & D Subsidy (\$/Kwe)	21 R & D Subsidy (mils/kw-hr)	22 Government Direct Costs (10^6 \$)
1956							249.1	249.1	∞	∞	500.1
1957					0.01	0.01	357.4	606.5	∞	60,650.0	612.2
1958					0.17	0.18	434.9	1,041.4	∞	5,785.6	699.0
1959					0.19	0.36	506.8	1,548.2	∞	4,300.6	783.3
1960			200	200	0.52	0.88	574.1	2,122.3	10,611.5	2,411.7	800.2
1961			175	375	1.69	2.57	642.5	2,764.8	7,372.8	1,075.8	741.0
1962			335	710	2.27	4.84	619.8	3,384.6	4,767.0	699.3	690.4
1963			68	778	3.21	8.06	716.4	4,101.0	5,271.2	508.8	695.4
1964				778	3.34	11.40	777.0	4,878.0	6,269.9	427.9	547.8
1965				778	3.66	15.06	776.0	5,654.0	7,267.4	375.4	500.4
1966			860	1,638	5.52	20.58	752.5	6,406.5	3,911.2	311.3	428.4
1967				1,638	7.66	28.33	801.0	7,207.5	4,400.2	255.3	389.9
1968			1,005	2,643	12.53	40.76	851.2	8,058.7	3,049.1	197.7	336.0
1969			1,298	3,941	13.93	54.69	812.8	8,871.5	2,251.1	162.2	371.0
1970			2,439	6,380	21.80	76.48	796.6	9,668.1	1,515.4	126.4	311.6
1971			2,713	9,093	37.90	114.38	793.8	10,461.9	1,150.5	91.5	273.1
1972	12.6	143.8	5,584	14,677	54.03	168.41	807.0	11,268.9	767.8	66.9	325.4
1973	10.6	141.0	5,587	20,264	83.29	251.71	880.8	12,149.7	599.6	48.3	358.6
1974	19.9	163.2	9,865	30,129	136.99	388.70	946.6	13,096.3	434.7	33.7	311.1
1975	16.7	200.8	6,323	36,452	171.40	560.10	1,205.5	14,301.8	392.3	25.5	463.0
1976	25.0	254.7	9,885	46,337	243.55	804.00	1,394.8	15,696.6	338.7	19.5	605.6
TQ	7.3	66.6	--	--	--	--	360.8	16,057.4	--	--	132.4
1977	34.0	287.8	6,631	52,968	278.40	1,082.00	1,695.6	17,753.0	335.2	16.4	824.5
1978	50.0	300.0	7,448	60,416	317.55	1,400.00	1,800.00	19,553.0	323.6	14.0	910.0
1979	50.0	300.0	10,979	71,395	375.25	1,775.00	1,800.0	21,353.0	299.1	12.0	910.0
1980	50.0	300.0	12,634	84,029	441.66	2,216.00	1,800.0	23,153.0	275.5	10.4	910.0
1981	50.0	300.0	14,632	98,661	518.56	2,735.00	1,800.0	24,953.0	252.9	9.1	910.0
1982	50.0	300.0	23,884	122,545	644.10	3,379.00	1,800.0	26,753.0	218.3	7.9	910.0
1983	50.0	300.0	19,065	141,610	744.30	4,123.00	1,800.0	28,553.0	201.6	6.9	910.0
1984	50.0	300.0	19,209	160,819	845.27	4,969.00	1,800.0	30,353.0	188.7	6.1	910.0
1985	50.0	300.0	11,314	172,133	904.73	5,873.00	1,800.0	32,153.0	186.8	5.5	910.0

TABLE E-III (Continued)

Year	23 Cumulative Direct Costs (10^6 \$)	24 Direct Cost Subsidy (\$/kwe)	25 Direct Cost Subsidy (mils/kw-hr)	26 Cumulative Governmental Subsidy (10^6 \$)	27 Total Subsidy (\$/kwe)	28 Total Subsidy (mils/kw-hr)	29 Money Index (1975 = 1.000)	30 Adjusted R & D (10^6 \$)	31 Adjusted Cumulative R & D (10^6 \$)	32 Adjusted R & D Subsidy (\$/kwe)	33 Adjusted R & D Subsidy (mils/kw-hr)
1956	500.1	∞	∞	749.2	∞	∞	2.009	500.4	500.4	∞	∞
1957	1,112.3	∞	111,230.0	1,718.8	∞	171,880.0	1.943	694.5	1,194.9	∞	119,949.0
1958	1,811.3	∞	10,062.8	2,852.7	∞	15,848.3	1.913	831.8	2,026.7	∞	11,259.4
1959	2,594.5	∞	7,206.9	4,142.7	∞	11,507.5	1.871	948.4	2,975.1	∞	8,264.2
1960	3,394.7	16,973.5	3,857.6	5,517.0	27,585.0	6,269.3	1.840	1,056.3	4,031.4	20,157.0	4,581.1
1961	4,135.7	11,028.5	1,609.2	6,900.5	18,401.3	2,685.0	1.824	1,171.8	5,203.2	13,875.2	2,024.6
1962	4,826.1	6,797.3	997.1	8,210.7	11,564.4	1,696.4	1.791	1,110.0	6,313.2	8,891.8	1,304.4
1963	5,521.5	7,097.0	685.0	9,622.5	12,368.3	1,193.9	1.765	1,264.4	7,577.6	9,739.8	940.1
1964	6,069.3	7,801.2	532.4	10,947.3	14,071.1	960.3	1.738	1,350.2	8,927.8	11,475.3	783.1
1965	6,569.7	8,444.3	436.2	12,223.7	15,711.7	811.7	1.700	1,319.3	10,247.1	13,171.1	680.4
1966	6,998.1	4,272.3	340.0	13,404.6	8,183.5	651.3	1.646	1,238.6	11,485.7	7,012.0	558.1
1967	7,388.0	4,510.4	261.7	14,595.5	8,910.6	517.0	1.599	1,280.8	12,766.5	7,794.0	452.2
1968	7,724.0	2,922.4	189.5	15,782.7	5,971.5	387.2	1.530	1,302.5	14,069.0	5,323.1	345.2
1969	8,095.0	2,054.0	148.0	16,966.5	4,305.1	310.2	1.457	1,184.2	15,253.2	3,870.4	278.9
1970	8,406.6	1,317.6	109.9	18,074.7	2,833.0	236.3	1.383	1,101.7	16,354.9	2,563.5	213.8
1971	8,679.7	954.5	75.9	19,141.6	2,105.1	167.4	1.316	1,044.5	17,399.4	1,913.5	152.1
1972	9,005.1	613.6	53.5	20,274.0	1,381.3	120.4	1.264	1,019.6	18,419.0	1,255.0	109.4
1973	9,363.7	464.1	37.2	21,513.4	1,061.7	85.5	1.193	1,050.7	19,469.7	960.8	77.3
1974	9,674.8	321.1	24.9	22,771.1	755.8	58.6	1.087	1,029.3	20,499.0	680.4	52.7
1975	10,137.8	278.1	18.1	24,439.6	670.5	43.6	1.000	1,205.5	21,704.5	595.4	38.8
1976	10,743.4	231.9	13.4	26,440.0	570.6	32.9	0.971	1,354.2	23,058.7	497.6	28.7
TQ	10,875.8	--	--	--	--	--	--	350.3	23,409.0	--	--
1977	11,700.3	220.9	10.8	29,453.3	556.1	27.2	0.943	1,598.3	25,007.3	472.1	23.1
1978	12,610.0	208.7	9.0	32,163.0	532.4	23.0	0.915	1,647.2	26,654.5	441.2	19.0
1979	13,520.0	189.4	7.6	34,873.0	488.5	19.6	0.888	1,599.3	28,253.8	395.7	15.9
1980	14,430.0	171.7	6.5	37,583.0	447.3	17.0	0.863	1,552.7	29,806.5	354.7	13.5
1981	15,340.0	155.5	5.6	40,293.0	408.4	14.7	0.837	1,507.5	31,314.0	317.4	11.4
1982	16,250.0	132.6	4.8	43,003.0	350.9	12.7	0.813	1,463.6	32,777.6	267.5	9.7
1983	17,160.0	121.2	4.2	45,713.0	322.8	11.1	0.789	1,420.9	34,198.5	241.5	8.3
1984	18,070.0	112.4	3.6	48,423.0	301.1	9.7	0.766	1,379.5	35,578.0	221.2	7.2
1985	18,980.0	110.3	3.2	51,133.0	297.1	8.7	0.744	1,339.4	36,917.4	214.5	6.3

[redacted] [redacted]

TABLE E-III (Concluded)

Year	34 Adjusted Direct Costs (10^6 $)	35 Adjusted Cumulative D.C. (10^6 $)	36 Adjusted D.C. Subsidy ($/kwe)	37 Adjusted D.C. Subsidy (mils/kw-hr)	38 Adjusted Total Subsidy ($/kwe)	39 Adjusted Total Subsidy (mils/kw-hr)
1956	1,004.6	1,004.6	∞	∞	∞	∞
1957	1,189.7	2,194.3	∞	219,430.0	∞	338,920.0
1958	1,336.9	3,531.2	∞	19,617.8	∞	30,877.2
1959	1,465.8	4,997.0	∞	13,880.6	∞	22,144.7
1960	1,472.3	6,469.3	32,346.5	7,351.5	52,503.5	11,932.6
1961	1,351.4	7,320.7	20,855.2	3,043.1	34,730.4	5,067.7
1962	1,236.5	9,057.2	12,756.6	1,871.3	21,648.5	3,175.7
1963	1,227.3	10,284.5	13,219.2	1,276.0	22,959.0	2,216.1
1964	951.9	11,236.4	14,442.7	985.6	25,918.0	1,768.8
1965	850.7	12,087.1	15,536.1	802.6	28,707.2	1,483.0
1966	705.2	12,792.3	7,809.7	621.6	14,821.7	1,179.7
1967	623.4	13,415.7	8,190.3	475.2	15,984.2	927.5
1968	514.2	13,929.9	5,270.5	341.8	10,593.6	686.9
1969	540.5	14,470.4	3,671.8	264.6	7,542.1	543.5
1970	530.9	14,901.3	2,335.6	194.8	4,899.1	408.7
1971	359.4	15,260.7	1,678.3	133.4	3,591.8	285.5
1972	411.1	15,671.8	1,067.8	93.1	2,322.7	202.4
1973	427.8	16,099.6	794.5	64.0	1,755.3	141.3
1974	338.3	16,437.9	545.6	42.3	1,226.0	95.0
1975	463.0	16,900.9	463.6	30.2	1,059.1	68.9
1976	588.0	17,488.9	377.4	21.8	875.1	50.4
TQ	128.5	17,617.4	--	--	--	--
1977	777.2	18,394.6	347.3	17.0	819.4	40.1
1978	832.8	19,227.4	318.3	13.7	759.4	32.8
1979	808.5	20,035.9	280.6	11.3	676.4	27.2
1980	785.0	20,820.9	247.8	9.4	602.5	22.8
1981	762.1	21,583.0	218.8	7.9	536.1	19.3
1982	739.9	22,322.9	182.2	6.6	449.6	16.3
1983	718.3	23,041.2	162.7	5.6	404.2	13.9
1984	697.4	23,738.6	147.6	4.8	368.8	11.9
1985	677.1	24,415.7	141.8	4.2	356.3	10.4

As of 1976, \$377/kwe have been invested in direct costs and \$498/kwe in nuclear R&D programs, making a total subsidy of \$875/kwe of installed nuclear capacity. By 1985, this subsidy will be reduced to \$336/kwe.

A similar treatment was used to distribute the funds expended by the government over the energy produced by the nuclear power plants as a function of time. The results are presented in Figure E-2. The 1976 figures indicate that 21.8 mills/kw-hr in direct costs and 28.7 mills/kw-hr in R&D programs have been spent, for a total subsidy of 50.5 mills/kw-hr. This is a subsidy several times the normally quoted busbar cost of nuclear power.